Prior and Future Research on Quality-Driven Product Service Systems: A Literature Review

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ABSTRACT

The role of services in manufacturing is increasing. Service becomes a value addition to the products offered. A product-service system (PSS) is a tangible manifestation of the integration of services and products. However, the integration of products and services must still ensure the quality of PSS. This paper aims to review the development of research related to the quality of PSS where products and services are considered as an integral part of the integration results. Previous research investigations were carried out by collecting journals discussing PSS. The quality of PSS was then discussed, and its mapping to the quality dimension. The mapping shows the research clusters that can be examined for emerging trends in research and potential future research. Those potential future researches are related to the dimension of reliability, durability, serviceability, aesthetic, and perceived quality.

CCS CONCEPTS

• **General and reference** → Document types; General literature.

KEYWORDS

The quality of PSS, PSS future research, literature review

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1 INTRODUCTION

Along with the increasing trend of servitization, The Product-Service System (PSS) also experienced a proportional increase. During the last thirty years, Servitization and The Product-Service System (PSS) have become interesting topics to be developed [1]. Manufacturing businesses have a tendency to integrate services into the tangible goods, a practice known as servitization [2]. The Product-Service System (PSS) is how this integration actually manifests itself [3]. In general, PSS can be defined as an integrated system of products, services, support networks, and infrastructure designed to meet customer needs, increase competitiveness, and have a lower environmental impact than traditional business models [4]. Based on this definition, PSS consists of product and service aspects. The dominance of product and service integration will shape the category and character of PSS. Individually, products and services have different characteristics. If these two aspects are integrated, there will be interactions that can influence the development of innovation between the two [5].

Therefore, managing PSS throughout its life cycle will be a challenge for the company. Companies will also face challenges in the case of having to control the quality of products and services simultaneously. The existence of integration between products and services often causes vague boundaries between product and service itself [6]. Consequently, quality control policies on product and service integration are becoming more complex. However, company must ensure the quality of PSS. The goal of this paper is to look at how research on the quality of PSS has changed over time, where products and services are seen as an important part of the integration results.

2 METHODOLOGY

Based on the background that has been described, previous research investigations were carried out by collecting journals discussing PSS. Additionally, journal filtering is conducted. Thirty journals addressing PSS quality were identified from the filtered results. Understanding each journal's contribution to the growth of PSS quality research, the journals have been mapped into eight quality aspects. There are eight quality dimensions used for the journal mapping process, namely performance, features, reliability, conformance, durability, serviceability, aesthetic and perceived quality [7]. Garvin, (1996) states that a product or service may score highly on one aspect of quality while scoring poorly on another, because one aspect of quality may be improved at the expense of another. This quality dimension is also used for service quality dimensions [8] and products [9]. With the addition of time to the research mapping, it becomes easier to see how past research has changed over time. Furthermore, journal clustering is carried out based on the topics discussed. This journal cluster can be used to see in detail research topics related to the quality dimension

3 LITERATURE REVIEW

PSS as a manifestation of servitization can be a new strategy in business innovation. Service involvement in manufacturing provides a

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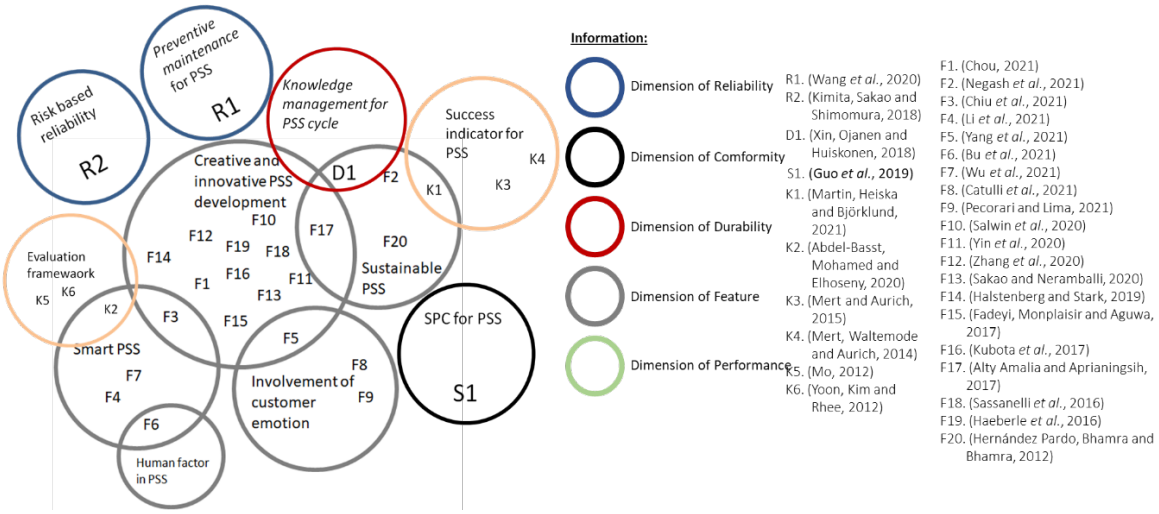

Figure 1: Previous Research Mapping ([22]; [23]; [24]; [25]; [26]; [27]; [28]; [29]; [30]; [31]; [13]; [32]; [12]; [10]; [33]; [20]; [21]; [34]; [35]; [36]; [37]; [16]; [17]; [14]; [15], [38], [18]; [19]; [39])

new package of offerings to customers in which the integration of products with services is inseparable [10]. The second definition of PSS that is widely used in the literature is the marketable set of products and services that are able to meet the user's needs [4]. The integration of products and services also changes how companies guarantee the quality of their products and services stays high. Customers also always want qualified PSS. Therefore, a literature review on the development of PSS research related to quality needs to be done. This is an effort by the company to follow business developments based on the development of customer taste.

Previous research reviews were carried out by reviewing relevant journals and clustering based on quality dimensions. The final goal of this paper is to find future research opportunities based on clusters of past research. Clustering of previous research can be done based on 8 dimensions of quality for products or services initiated by Garvin (1996). The results of the clustering of thirty journals are as Figure 1. On the feature dimension, there are 20 studies about PSS quality that can be grouped into 5 research topics: creative and innovative PSS development, sustainable PSS, customer emotional involvement, taking human factors into account in PSS, and smart PSS.

The densest cluster discusses how to develop PSS in unique ways, such as design by involving technology [11], personalization [12], and by using the TRIZ method, which emphasizes innovation [13]. PSS design can also be done by conducting system modeling [14, 15], optimization [16], and the use of big data [17]. From this cluster, it was found that the design of service integration with products should be carried out as early as possible in the early stages of design [18] and the selection of service parameters should be carried out systematically on existing product design methods [19].

The next cluster in this dimension is smart PSS, which involves technology features. This cluster has a wedge with the creative and innovative PSS development cluster. These slices are research that discusses the development of smart PSS by personalizing [12] and research that discusses human factors in PSS [20]. Other research on smart PSS clusters is the development of smart PSS by considering cyber-physical resources [11], and optimizing smart PSS with function orientation [21].

The next two clusters are the sustainable PSS and the customer's emotional involvement in the PSS. Negash et al. (2021) developed a sustainable PSS, taking into account the uncertainties in the pharmaceutical industry. Meanwhile, two other studies in the sustainable PSS cluster discuss the design of PSS for small and medium enterprises [39], such as in herbal medicine companies [38]. Meanwhile, research to explore emotional needs was carried out by Catulli et al. (2021) through a social experiment; Pecorari & Lima, (2021) through testing the relationship between experience and customer acceptance; and Yang et al., (2021) through exploring emotional needs on smart PSS. The next dimension is performance, which consists of two clusters, namely PSS success indicator and evaluation framework. Research on the PSS success indicator cluster discusses the evaluation of PSS by capturing several success measures, such as the environmental impact indicators provided [26], key performance indicators of the PSS development project [28], and quality measures of the PSS development project. PSS [29]. Research on the evaluation framework cluster provides a management for evaluating PSS, such as a framework for evaluating innovation value propositions (IVP) on smart PSS [27], a framework for engineering PSS using complex engineering products and service systems [30], and a framework for designing new PSS [31].

The next dimension is reliability, which consists of two studies. The first study is related to efforts to create a reliable PSS through failure analysis [23]. The second study is related to preventive maintenance for PSS [22]. In this study, there will be an adjustment of the method for the service aspect and its integration with the product aspect.

Table 1: Summary Information of Research Mapping

No	Dimension of Quality	Research Topic	Amount	Implication
1	**Reliability**	Risk based reliability	1	High opportunity to be investigated
		Preventive maintenance for PSS	1	High opportunity to be investigated
2	Conformity	Statistical Process Control for PSS	1	High opportunity to be investigated
3	Durability	Knowledge management for PSS cycle	1	High opportunity to be investigated
4	**Feature**	Creative and innovative PSS development	13	Variative research topic but congestion
		Sustainable PSS	2	Trending research concern
		Involvement of customer emotion	2	Trending research concern
		Human factor in PSS	1	Trending research concern
		Smart PSS	2	Trending research concern
5	**Performance**	Evaluation framework	3	Expanded research area for PSS
		Success indicator for PSS	3	Expanded research area for PSS
6	Aesthetic	-	-	Explorable new research area for PSS
7	Service-ability	-	-	Explorable new research area for PSS
8	Perceived quality	-	-	Explorable new research area for PSS

Another quality dimension is durability and suitability. This dimension gets the smallest percentage value. A study on the durability dimension discusses the application of knowledge management in the entire PSS life cycle [24]. Meanwhile, a study on the dimensions of conformity was carried out by Guo et al. (2019), who used turtle diagrams to analyze discrepancies that occurred in PSS, both in product and service aspects. If there is a discrepancy, it can be said that the PSS that has been designed is of poor quality and must be repaired immediately to make it better. When viewed from the year of research, this research is still relatively new. Thus, it can be said that the development of research for the dimension of suitability is still relatively slow.

4 RESULT AND DISCUSSION

Each quality dimension has a different focus. As a result, these variations become reason why research on each of its dimensions has developed differently. While each dimension has an impactful role in the running of the company. This mapping will be useful to know the development of research from time to time for each dimension. Furthermore, research opportunities can be identified to complement slow research progress. This previous research mapping can also be used to evaluate research equity on the topic of PSS quality. Tabular 1 provides a summary of the information that can be acquired from Figure 1.

Deployed research on the topic of PSS quality will be needed for the availability of references that can support the development of PSS itself. Thus, it is important to do a literature review to see the development of research on PSS quality. The results of adding the time variable to journal mapping are presented in Figure 2.

The intensity of the research is seen in the dimensions of the features, so that information can be obtained that research related to how to design or develop PSS to obtain appropriate features develops from time to time, with an increasing trend in 2021. Based on the 30 journals reviewed, it is also seen that research on PSS reliability only appeared in 2018 and another study reappeared in 2020. This shows the lack of research that wants to be conducted on PSS reliability. This dimension shows a very sharp decrease in

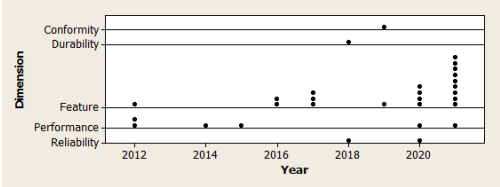

Figure 2: Timeline of previous research

the number of studies compared to the features and performance dimensions. This can be used as a good research opportunity to be developed. There are many research areas in the reliability of PSS that have not been discussed. Previous studies can be used as stepping stones for further research. Some of the things that can be studied are the reliability of PSS and the preventive maintenance efforts for some PSS characters.

Research developments in the dimensions of conformity and durability have the same character. Of the 30 journals reviewed, there was only one study dating to 2018. This shows that research on the topic of durability for PSS is a rare topic with slow research progress. It is clear that studies about the durability of PSS only began to be published in 2018, and until now there has still been no research that discusses the durability of PSS. Existing research on topics like the role of knowledge management in making PSS last longer and how to control PSS conformity can lead to new research ideas in this area. Other research opportunities can also be carried out on the dimensions of serviceability, aesthetics, and perceived quality. Based on the mapping of 30 previous studies that have not been seen, research related to PSS that discusses serviceability, aesthetics, and perceived quality.

5 CONCLUSION

Based on the literature review and mapping of previous PSS quality research, it can be concluded that PSS quality research is dominated by the feature dimension, which means a lot of research on how to design and develop PSS so that it can be accepted by customers.

In addition, the slow development of research is shown in the dimensions of reliability, durability, serviceability, aesthetics, and perceived quality. Thus, future research can be focused on these dimensions.

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REFERENCES

[1] Abdel-Basst, M., Mohamed, R. and Elhoseny, M. 2020. A novel framework to evaluate innovation value proposition for smart product–service systems. Environmental Technology and Innovation. 20, (Nov. 2020). DOI:https://doi.org/10.1016/j.eti.2020.101036.

[2] Alty Amalia, F. and Aprianingsih, A. 2017. Business Model of Jamu as Indonesian Traditional Herbal Medicine in New Economy. The Asian Journal of Technology Management. 10, 1 (2017), 19–28. DOI:https://doi.org/10.12695/ajtm.2017.10.1.3.

[3] Annarelli, A., Battistella, C., Costantino, F., di Gravio, G., Nonino, F. and Patriarca, R. 2021. New trends in product service system and servitization research: A conceptual structure emerging from three decades of literature. CIRP Journal of Manufacturing Science and Technology. Elsevier Ltd.

[4] Bu, L., Chen, C.H., Ng, K.K.H., Zheng, P., Dong, G. and Liu, H. 2021. A user-centric design approach for smart product-service systems using virtual reality: A case study. Journal of Cleaner Production. 280, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.124413.

[5] Catulli, M., Sopjani, L., Reed, N., Tzilivakis, J. and Green, A. 2021. A socio-technical experiment with a resource efficient product service system. Resources, Conservation and Recycling. 166, (Mar. 2021). DOI:https://doi.org/10.1016/j.resconrec.2020.105364.

[6] Chiu, M.C., Huang, J.H., Gupta, S. and Akman, G. 2021. Developing a personalized recommendation system in a smart product service system based on unsupervised learning model. Computers in Industry. 128, (2021), 103421. DOI:https://doi.org/10.1016/j.compind.2021.103421.

[7] Chou, J.R. 2021. A TRIZ-based product-service design approach for developing innovative products. Computers and Industrial Engineering. 161, 1 (2021), 107608. DOI:https://doi.org/10.1016/j.cie.2021.107608.

[8] Fadeyi, J.A., Monplaisir, L. and Aguwa, C. 2017. The integration of core cleaning and product serviceability into product modularization for the creation of an improved remanufacturing-product service system. Journal of Cleaner Production. Elsevier Ltd.

[9] Garvin, D.A. 1996. Competing on the eight dimensions of quality. IEEE Engineering Management Review. 24, 1 (1996), 15–23.

[10] Guo, H., Zhang, R., Chen, X., Zou, Z., Qu, T., Huang, G., Shi, J., Chen, M., Gu, H., Lun, Y., Li, J. and He, Z. 2019. Quality control in production process of product-service system: A method based on turtle diagram and evaluation model. Procedia CIRP (2019), 389–393.

[11] Haase, R.P., Pigosso, D.C.A. and McAloone, T.C. 2017. Product/Service-System Origins and Trajectories: A Systematic Literature Review of PSS Definitions and their Characteristics. Procedia CIRP. 64, (2017), 157–162. DOI:https://doi.org/10.1016/j.procir.2017.03.053.

[12] Haeberle, D., Imran, S., van Husen, C. and Droll, C. 2016. A New Approach for the Development of Services for Industrial Product-Service Systems. Procedia CIRP (2016), 353–357.

[13] Halstenberg, F.A. and Stark, R. 2019. Study on the feasibility of modelling notations for integrated product-service systems engineering. Procedia CIRP (2019), 157–162.

[14] Hernández Pardo, R.J., Bhamra, T. and Bhamra, R. 2012. Sustainable product service systems in Small and Medium Enterprises (SMEs): Opportunities in the leather manufacturing industry. Sustainability. 4, 2 (2012), 175–192. DOI:https://doi.org/10.3390/su4020175.

[15] Kimita, K., Sakao, T. and Shimomura, Y. 2018. A failure analysis method for designing highly reliable product-service systems. Research in Engineering Design. 29, 2 (Apr. 2018), 143–160. DOI:https://doi.org/10.1007/s00163-017-0261-8.

[16] Li, X., Lyu, M., Wang, Z., Chen, C.H. and Zheng, P. 2021. Exploiting knowledge graphs in industrial products and services: A survey of key aspects, challenges, and future perspectives. Computers in Industry. 129, (2021), 103449. DOI:https://doi.org/10.1016/j.compind.2021.103449.

[17] Li, X., Wang, Z., Chen, C.H. and Zheng, P. 2021. A data-driven reversible framework for achieving Sustainable Smart product-service systems. Journal of Cleaner Production. 279, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.123618.

[18] Mahut, F., Daaboul, J., Bricogne, M. and Eynard, B. 2015. Survey on product-service system applications in the automotive industry. IFAC-PapersOnLine. 28, 3 (2015), 840–847. DOI:https://doi.org/10.1016/j.ifacol.2015.06.188.

[19] Martin, M., Heiska, M. and Björklund, A. 2021. Environmental assessment of a product-service system for renting electric-powered tools. Journal of Cleaner Production. 281, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.125245.

[20] Mert, G. and Aurich, J.C. 2015. A software demonstrator for measuring the quality of PSS. Procedia CIRP (2015), 209–214.

[21] Mert, G., Waltemode, S. and Aurich, J.C. 2014. Quality assessment of technical product-service systems in the machine tool industry. Procedia CIRP (2014), 253–258.

[22] Mo, J.P.T. 2012. Performance assessment of product service system from system architecture perspectives. Advances in Decision Sciences.

[23] Mustafa, M., Sivarajah, U., Ziaee, A. and Missi, F. 2020. Servitization implementation in the manufacturing organisations: Classification of strategies , definitions , benefits and challenges. International Journal of Information Management. 55, July (2020), 102206. DOI:https://doi.org/10.1016/j.ijinfomgt.2020.102206.

[24] Negash, Y.T., Calahorrano Sarmiento, L.S., Tseng, M.L., Jantarakolica, K. and Tan, K. 2021. Sustainable product-service system hierarchical framework under uncertainties: The pharmaceutical industry in Ecuador. Journal of Cleaner Production. 294, (2021), 126188. DOI:https://doi.org/10.1016/j.jclepro.2021.126188.

[25] Nijssen, E.J., Hillebrand, B., Vermeulen, P.A.M. and Kemp, R.G.M. 2006. Exploring product and service innovation similarities and differences. International Journal of Research in Marketing. 23, 3 (2006), 241–251. DOI:https://doi.org/10.1016/j.ijresmar.2006.02.001.

[26] Pecorari, P.M. and Lima, C.R.C. 2021. Correlation of customer experience with the acceptance of product-service systems and circular economy. Journal of Cleaner Production. 281, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.125275.

[27] Rondi, E., de Massis, A. and Kraus, S. 2021. Servitization through open service innovation in family firms: Exploring the ability-willingness paradox. Journal of Business Research. 135, (2021), 436–444. DOI:https://doi.org/10.1016/j.jbusres.2021.06.040.

[28] Sachdev, S.B. and Verma, H.V. 2004. Relative Importance of Service Quality Dimensions: A Multisectorial Study. Journal of Services Research. 4, 1 (2004), 93–116.

[29] Sakao, T. and Neramballi, A. 2020. A product/service system design schema: Application to big data analytics. Sustainability (Switzerland). MDPI AG.

[30] Salwin, M., Kraslawski, A., Lipiak, J., Gołębiewski, D. and Andrzejewski, M. 2020. Product-Service System business model for printing houses. Journal of Cleaner Production. 274, (Nov. 2020). DOI:https://doi.org/10.1016/j.jclepro.2020.122939.

[31] Sassanelli, C., Pezzotta, G., Pirola, F., Terzi, S. and Rossi, M. 2016. Design for Product Service Supportability (DfPSS) Approach: A State of the Art to Foster Product Service System (PSS) Design. Procedia CIRP (2016), 192–197.

[32] Wang, N., Ren, S., Liu, Y., Yang, M., Wang, J. and Huisingh, D. 2020. An active preventive maintenance approach of complex equipment based on a novel product-service system operation mode. Journal of Cleaner Production. 277, (Dec. 2020). DOI:https://doi.org/10.1016/j.jclepro.2020.123365.

[33] Withers, B. and Diego, S. 2000. Does ISO 9000 Certification Affect the Dimensions of Quality Used for Competitive Advantage? European Management Journal. 18, 4 (2000), 431–443.

[34] Wu, C., Chen, T., Li, Z. and Liu, W. 2021. A function-oriented optimising approach for smart product service systems at the conceptual design stage: A perspective from the digital twin framework. Journal of Cleaner Production. 297, (May 2021). DOI:https://doi.org/10.1016/j.jclepro.2021.126597.

[35] Xin, Y., Ojanen, V. and Huiskonen, J. 2018. Knowledge Management in Product-Service Systems - A Product Lifecycle Perspective. Procedia CIRP (2018), 203–209.

[36] Yang, X., Wang, R., Tang, C., Luo, L. and Mo, X. 2021. Emotional design for smart product-service system: A case study on smart beds. Journal of Cleaner Production. 298, (May 2021). DOI:https://doi.org/10.1016/j.jclepro.2021.126823.

[37] Yin, D., Ming, X., Liu, Z. and Zhang, X. 2020. A fuzzy ANP-QFD methodology for determining stakeholders in product-service systems development from ecosystem perspective. Sustainability (Switzerland). 12, 8 (Apr. 2020). DOI:https://doi.org/10.3390/SU12083329.

[38] Yoon, B., Kim, S. and Rhee, J. 2012. An evaluation method for designing a new product-service system. Expert Systems with Applications. 39, 3 (Feb. 2012), 3100–3108. DOI:https://doi.org/10.1016/j.eswa.2011.08.173.

[39] Zhang, Z., Xu, D., Ostrosi, E. and Cheng, H. 2020. Optimization of the product-service system configuration based on a multilayer network. Sustainability (Switzerland). 12, 2 (Jan. 2020). DOI:https://doi.org/10.3390/su12020746

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MESSAGE FROM RECTOR

The Covid-19 pandemic has substantially posed challenges to the world of a magnitude that we did not specifically anticipate before. On the other hand, it has also opened up new possibilities for technology and innovation in our daily lives and workplaces. In the post-pandemic period that we are experiencing at present, technology and innovation play even bigger roles to improve effectiveness and sufficiency for sustainability on our planet with a particular emphasis on human wellbeing. Despite the size of the task and the current unpredictable path of the world, the transformation to a sustainable future is not impossible because we have the knowledge, tools, and capacity.

Therefore, bringing forward the theme "Fostering Innovation and Technology for the Sustainability of the Post-Pandemic Society", our International Conference on Innovation, Entrepreneurship, and Technology (ICONIET) this year serve as a forum where academics, researchers, industry practitioners, and government officials discuss the significance of innovation, research, and technology in presenting potential solutions for establishing a sustainable future for people and the environment.

For the last seven years, Swiss German University has been regularly conducting the ICONIET as a token of contribution to quality research and education. This year, the ICONIET consists of two sub-conferences, namely "International Conference on Engineering and Information Technology for Sustainable Industry 2022 (ICONETSI)" on 21-22 September 2022 and "International Conference on Biomedical and Pharmaceutical Sciences and Technology (ICOBIPST) on 1 and 2 October 2022.

I'd like to take this opportunity to welcome all honourable speakers, presenters, and participants from Indonesia and other countries. I wish to express my gratitude to the Minister of Communication & Information of the Republic of Indonesia, Mr. Johny G Plate for his tremendous support in this conference. I'd like to further thank the Ministry of Research and Technology as well as the National Research & Innovation Agency (BRIN) for their continuous support of our research. Our deep appreciation also goes to the University of Brawijaya Faculty of Medicine, the co-host of the first ICOBIPST at this conference. Last but surely not the least, I'd like to thank the Committee of ICONIET 2022, including the committee of ICONETSI and ICOBIPST 2022, who have put their utmost efforts into organizing these events.

I wish all participants to experience insightful and productive times in this conference. I hope this event will give invaluable new ideas and potential solutions for establishing a sustainable future in these challenging times. We look forward to seeing all of you at the ICONIET 2022.

Respectfully yours,

Dr. rer. nat. Filiana Santoso
Rector of Swiss German University

MESSAGE FROM CONFERENCE CHAIR

On behalf of the organizing committee, it is my pleasure and privilege to welcome you to the 2nd International Conference on Engineering and Information Technology for Sustainable Industry (ICONETSI 2022).

Under the theme of "Innovation and Technology for Resilient and Sustainable Industry", the conference offers a platform for scholars, engineers, scientists, practitioners, and students from universities and industries around the world to perform knowledge exchanges about research and development activities.

This conference features a rich program, including a keynote speech delivered by honourable Minister of Communication and Informatics Republic of Indonesia - Mr. Johnny G. Plate, and also keynote speech from Dr. R. Herdian – Deputy for Utilization of Research and Innovation BRIN. In the plenary session, the speeches will be delivered by Dr. Nuki Agya Utama - Executive Director at ASEAN Center for Energy and Assoc. Prof. Dr. Waseem Haider from Central Michigan University, while in the parallel session, we are delighted to have Prof. Dr. Dominik Aufderheide from Fachhochschule Südwestfalen, Germany, Prof. Dr.-Ing. Matthias Schirmer from Ernst-Abbe-Hochschule Jena, Germany, Prof. Dr. Wahyudi Sutopo from Lithium Battery Research and Technology Centre, Universitas Sebelas Maret, Surakarta, Indonesia, Dr. Selvakumar Ramachandran from Kerckhoffs Ltd, United Kingdom, and Kholis Abdurachim Audah, Ph.D from Swiss German University; Indonesia

All accepted and presented papers in this conference will have the opportunities to be published in ACM International Conference Proceeding Series and indexed by Scopus. The conference has received 92 submitted papers from Japan, France, Taiwan, Peru, Saudi Arabia, and Indonesia whereby 68 papers have been accepted by the committee for presentation and to be included in the proceedings. Each submission is evaluated by at least three reviewers in a blind review procedure to guarantee the high quality of the articles. Additionally, we thoroughly review each submission's writing style in accordance with the conference proceedings template and the similarity rating to prevent plagiarism.

I would like to express my highest gratitude to every one of the organizing committee members, the reviewers, the moderators, the session chairs, the collaboration partners, the volunteers, and the sponsors for their amazing efforts in making this conference successful.

Thank you for being here with us. We value your presence at this conference. Enjoy the conference!

Warm Regards,
Dr. Eng. Aditya Tirta Pratama
ICONETSI 2022 General Chair

Keynote Speaker

Development and Characterization of Thin Film Metallic Glasses for Biomedical Applications

Assoc. Prof. Dr. Waseem Haider
Central Michigan University, USA

Abstract:

Novel thin film metallic glasses are synthesized for advanced biomedical applications using magnetron co-sputtering. The formation and properties of metallic glasses are optimized via compositional variations using power densities of sputtering gun. These films are subsequently characterized for surface, electrochemical and mechanical properties. The structural characterizations are done using Glancing-angle X-Ray Diffraction, Transmission Electron Microscopy and X-Ray Photoelectron Spectroscopy. Moreover, the electrochemical characterizations are carried out using Potentiodynamic polarization and Impedance spectroscopy. This research offers a new way of synthesizing metallic glasses for advanced applications.

Short Biography:

Dr. Waseem Haider is a tenured associate professor at School of Engineering and Technology, Central Michigan University, USA. He earned his PhD in Mechanical Engineering from Florida International University in 2010. He got a post-doctoral fellowship in materials science and engineering at Pennsylvania State University. Afterwards, he joined orthopedic research labs as a research scientist at State University of New York. Soon after that, he joined University of Texas as tenure track assistant professor where he served for three years. Dr. Haider's research focuses on Materials Science and Biomedical Engineering with special emphasis on Biomedical Materials Surface Chemistry, Electrochemistry, Bulk Metallic Glasses, and Nanomaterials. His research is supported by National Science Foundation and Department of Defense.

Keynote Speaker

Strategic Energy Transition for ASEAN

Dr. Nuki Agya Utama
Executive Director of the ASEAN Centre for Energy (ACE)

Abstract:

The ASEAN economic growth has been one of the fastest in the world, which needs to be fueled by energy. The 6th ASEAN Energy Outlook (AEO6) projected that the primary energy supply in 2040 will be 2.1 times higher than the 2017 level. Still dominated by fossil fuels, ASEAN will become a net importer of gas starting in 2025 and coal starting in 2035—assuming no significant exploration. With the volatility of fossil fuel markets, energy security needs to be addressed in the region's energy transition.

The region, through the ASEAN Plan of Action for Energy Cooperation (APAEC), put energy security as one of its four pillars, along with accessibility, affordability, and sustainability. Within that are the regional energy targets, achieving 23% of RE share in TPES, 35% of RE in installed power capacity, and 32% energy intensity reduction by 2025. Nevertheless, a just energy transition would require ASEAN to secure its energy supply by optimizing the energy mix from the indigenous primary energy sources. The importance of geopolitics, diversification of energy sources, and improvement of capacity and technology are seen to be key strategies.

Short Biography:

Dr. Nuki Agya Utama is appointed as the Executive Director of the ASEAN Centre for Energy (ACE) and reporting directly to an International organisation under ASEAN entities and reporting to Governing Council consist of ministries energy in ASEAN member states. He is currently an advisory board member of Asia Pacific Energy Research Centre (APERC) and World Economic Forum (WEF) Global Future Councils.

Dr. Nuki Agya Utama has academics and research background as Post-Doctorate in Graduate School Energy Science Kyoto University for energy scenario planning in South East Asia. Holding PhD, with research on Life Cycle Energy Analysis from Joint Graduate School of Energy and Environment, the University of Technology King Mongkut (KMUTT), Thailand.

Prior to assuming his position in ACE, he worked as a director various local companies and as a consultant in a well-known international Institutions. In his early career, he worked as a consultant in UNDP and UNEP, working on energy and environment-related issues. He also serves as an invited lecture in Diponegoro University as well as editor and reviewer in a various international journal.

Invited Speaker

The Indonesian Natural Products Library: an Indonesian Natural Products Database for Drug Discovery

Kholis Abdurachim Audah, PhD.
Director of Academic Research and Community Service
Swiss German University

Abstract:

Indonesia is one of megabiodiverse countries in the world which has abundant natural resources both on land and marine. Natural resources have been utilized as the resources for traditional medicines that have been practices for generations. The term natural product refers to natural resource, mainly biota, that has medicinal benefits. Various researches on natural products have been vigorously conducted in Indonesia, especially since 2015 when the Indonesian government launched a National Research Plan (2015-2044). In this plan, research on natural products had become country's top research priority. Despite this positive atmosphere for natural products researches, researches conducted are still scattered and lack of coordination, communication or collaboration among researchers and or institutions. One of the problems to this condition is due to the absence of a common database platform for scientist to display their works. The platform can be used as the source of information so that people can follow and learn about different research that have been conducted, on what areas and the stage of the researches.

The Indonesian Natural Products Library (INPL) is developed to solve this problem to ensure that all researches utilizing Indonesian biodiversity, particularly in the area of drug discovery or pharmaceuticals, are more effectively done. As the source of information, INPL will enable the synchronizing and synergizing Indonesia's natural products-based research so that unnecessary activities such as overlapping and discontinuation of researches can be avoided. In addition, INPL will also be useful for finding alternatives for other areas such as food and energy sources.

Short Biography:

Dr. Audah earned his PhD in Biochemistry from Auburn University, USA (2007). He did his Postdoctoral Research at Yale University School of Medicine, Section of Infectious Diseases (2009). Dr. Kholis Audah earned his Bachelor Degree in Chemistry/

Biochemistry from Bogor Agricultural University, Indonesia (1996) and a Master Degree in Molecular Biology from University of Malaya, Malaysia (2000). Currently, he serves as the Director of Research and Community Services and Senior Lecturer at Department

of Biomedical Engineering, Swiss German University (SGU), Tangerang (2015-present). Before joining SGU, he held different positions at different institutions in Indonesia, Saudi Arabia and USA.

His current researches focus on Drug Discovery on antibacterial and anticancer from Indonesian natural products as well as synthetic compounds and Telemedicine. His project in Development of Mangrove Extract Library for Drug Discovery and Development of Microscope Scanner for Telepathology were funded by the Ministry of Research and Higher Education, Republic of Indonesia. He also obtained international and industrial funding as well as Awards from various institutions. He is the inventor of the Indonesian Natural Products Library (INPL) and the Citizen Medicine (CitMed) databases.

Dr. Audah is actively involved in different scientific organizations and scientific activities as Editor in Chief, Editorial Board Members and Reviewer in several national and international journals. Before joining SGU, Dr Audah was the Head of Biochemistry Departments and Laboratory and Assistant Professor at the College of Medicine, University of Hail, Hail, Saudi Arabia. He was also the Lead Scientist (Research and Laboratory) for the establishment of the Indonesia Medical Education and Research Institute (IMERI), Faculty of Medicine, University of Indonesia. He earned some professional certifications such as Good Clinical Practice from the Indonesian Association for the Study of Medicinal, Certified Reviewer from Kemenristekdikti and ISO 17024 and Certified Biosafety Level 2 and Radioisotope handling, Yale University.

Invited Speaker

Therapeutic Potential of Organic Fermented Soybean Extract Against Lead (Pb)-Induced Zebrafish Via NMR Metabolomics Approach

Assoc. Prof. Dr. Intan Safinar Ismail
Dean of Faculty of Science, University of Putra Malaysia

Abstract:

Lead (Pb), even in small quantity, is harmful to multiple body systems. Dimercaptosuccinic acid (DMSA), one of the chelators that used to treat Pb toxicity also gives various negative side effects. Tempeh, one of the fermented soybeans is known having high antioxidant effect which might potentially be useful in alleviation of Pb toxicity. Organic foods are sold with a higher price than the non-organics as the organics are claimed to be better in terms of health benefits. However, the difference in the phytochemical content between organic and non-organic soybeans that related to their quali-ties is not well explored. Thus, this study assessed the therapeutic potential of organic fermented soybean extracts (FSE) against Pb toxicity using a zebrafish model. Non-targeted NMR metabolomics was used to study the difference in the chemical profiles between non-organic and organic soy-beans (Glycine max [L.] Merr.), and the metabolite changes after fermentation using Rhizopus oligosporus. The Pb and FSE concentrations were preliminary investigated before proceeding further with the therapeutic study of FSE against Pb toxicity in zebrafish model. All zebrafish samples were evaluated using NMR metabolomics with additional support behavioral test and transmission electron microscope (TEM) analysis. Zebrafish that exposed to 50 mg/L FSE significantly changed four metabolites namely glucose, isoleucine, sn-glycero-3-phosphocholine, and glutamine. Preliminarily study of Pb inducement significantly altered the behavior of zebrafish and non-lethal 5 mg/L Pb concentration which altered the metabolite profiles of zebrafish are selected for further investigation. In the therapeutic study, citrulline was significantly upregulated only in Pb-induced group without any treatment.

FSE-treated (50mg/L) Pb-induced zebrafish might potentially retrieve the effect of Pb toxicity by significantly upregulated four key differential metabolites (glutamine, glutamate, glutathione, and taurine). Even though the treatment groups (FSE and DMSA) did not normalize to control, yet they differ from Pb-induced group without any treatment. These results presumed that FSE has potential to ameliorate the Pb poisoning effect in this fish model.

Short Biography:

Associate Professor Dr. Intan Safinar Ismail completed her PhD and post-doctoral studies at Okayama University and Hoshi Medical University, Japan. She joined Universiti Putra Malaysia (UPM) in 2005 and became the Head of Laboratory of Natural Products at the Institute of Bioscience in 2011 until 2017. She is now the Head of Chemistry Department, Faculty of Science. Within the period of her affliation to the Universiti Putra Malaysia, she has published more than 190 papers in reputed journals and presentations at conferences as speakers including keynote and invited at international meetings. She led 14 research projects and leading 2 at the moment and more than 5 as a co-worker. Seven Ph.D. and 13 MSc students have graduated under her supervision, with 3 Ph.D. and 1 MSc students are currently enrolling. She co-supervised more than 50 postgraduates. She is editor for a few journals including Journal of Natural Medicines (Springer), review editor for Marine Biotechnology (Frontiers) and Specialty Section of Natural Products (Frontiers).

Invited Speaker

Current Challenges of the Energy Market - Between Net Zero Scenario and Security of Energy Supply

Prof. Dr.-Ing Matthias Schirmer
EAH Jena, Germany

Abstract:

With the adoption of the climate targets, the European energy market is facing a fundamental transformation. Fossil energy sources must be replaced by low-emission, renewable types of energy production. In the field of electricity generation, some successes have been achieved in the last decade. The share of renewable energies in electricity generation in the EU-27 was 22% last year. Greenhouse gas emissions have been reduced by 32% since 1990. These successes should not obscure the challenges that lie ahead, especially in the heat supply and mobility sectors. The war in Ukraine has further aggravated this situation. In addition to the goal of reducing emissions, the main concern now is to secure the energy supply. This raises the question of how to reduce dependence on Russian oil and gas supplies. Furthermore, how can we deal with energy prices, which have risen drastically in some cases? In the following, the current situation of the European energy market will be analyzed, and possible solutions discussed.

Short Biography:

Prof. Dr.-Ing. Matthias Schirmer is Professor for Energy and Environment (W2) at the Faculty of Industrial Engineering at the University of Applied Science Jena, Germany. He is currently a Vice- Dean of the Faculty Industrial Engineering and Director of the post graduate study program "Environmental and Geo resource Management". Prof. Dr.-Ing. Matthias Schirmer has academics and research background as PhD thesis (Dr.-Ing.) Dresden University of Technology, with research on Waste characterization and energy generation by waste and biomass, and also Energy systems modelling and simulation. He has experienced in various teaching, research and project stays in Portugal, Greece, Peru, Chile, Ecuador, Indonesia, Vietnam, Thailand, India, Namibia and South Africa.

Invited Speaker:

Emerging Technologies for ALL

Dr. Selvakumar Ramachandran
Kerckhoffs Ltd, UK

Abstract:

In human history 'technological' revolutions brought in a greater level of playing field for society. It has not just created opportunities and created wealth, but it strengthened the connectivity, human bonding even stronger. Given the advancement in telecommunications, particularly 5G combined with VR/AR, innovators and researchers believe that it can bring a greater level of inclusion and accessibility in several domains. We, at Kerckhoffs Ltd, creating Eyemmersive - an inclusive VR-based tourism platform for all, connecting VR-content creators to the people who want to have alternative platform to have parallel tourism and a tool to plan before they travel. Dr Ramachandran will speak about VR in accessible tourism and how it can support inclusion in other domains

Short Biography:

Dr Selvakumar Ramachandran is the CEO of UK based software R & D company Kerckhoffs Ltd. Dr Ramachandran is one of the pioneers in the field of emerging technologies and a flag bearer promoting technology for all. Dr Ramachandran earned his PhD from University of Rome – Tor Vergata, Italy and he received his MSc degree from Blekinge Tekniska Hogskola, Sweden. Dr Ramachandran has for 20+ years of experience in the field of computer science, published several papers and was a recipient of Google Scholar award in the year 2012.

Invited Speaker:

Intelligent Systems and Strategies for a Sustainable Cement Manufacturing

Prof. Dr.-Ing. Dominik Aufderheide
Fachhochschule Südwestfalen, Germany

Abstract:

Approximately 4-8% of the total global emissions of carbon dioxide (CO2) are caused by the usage of concrete. Here, especially the process of cement manufacturing is very energy intensive and the usage of large amounts of fossil fuels is typically involved within the main clinkering process. Therefore, the usage of Alternative Fuel Resources (AFR) has become a main technique towards a greener cement production. Due to the volatile combustion characteristics of those bulk materials, the process control has become a challenge for plant operators. This talk provides an overview of recent methodologies for the optimization of cement plants in order to reduce the associated environmental impact. In this context, especially intelligent system architectures and model-based optimization techniques are introduced and discussed. Furthermore, the incorporation of sensors and vison-based approaches for a model-based process optimization are evaluated.

Short Biography:

Prof. Dr. Dominik Aufderheide is a full professor for industrially metrology at the Faculty of Electrical Engineering at the South Westphalia University of Applied Sciences. His research interests are intelligent sensor systems, computer vision, model-based design and optimisation techniques and energy optimization. Before he returned to academia in 2020, he worked for several years as the head of automation and research at the Di Matteo Group in Beckum, Germany, where he led several development and research projects related to the process optimization in energy-intensive industries, such as cement and steel production or in electrical power plants. He graduated in 2014 from the University of Bolton, U.K. as a Ph.D. with a dissertation about the self-acting 3D scene reconstruction based on a novel sensor-fusion approach. At the same university, he received his Master's degree in Electronic Systems and Engineering Management with Distinction in 2009. Before that he studied Electrical Engineering and Industrial Informatics at the South Westphalia University of Applied Sciences in Soest, Germany.

Invited Speaker 4:

Accelerating A Commercialization of The Innovation Technology Using Early Supply Chain and Standardization:

A Case Study of Energy Storage Technology

Prof. Dr. Ir. Wahyudi Sutopo, ST., M.Si, IPM.
Universitas Sebelas Maret

Abstract:

In most cases, many technology products resulting from research happened to fail to be launched to the market due to the valley of death. This obstacle usually occurs in the transition process between technology development and technology commercialization. Hence, critical action is needed to accelerate the technology commercialization to ensure the commercialization potency of research output does not fall into the valley of death. The innovation of the Electric Motorcycle Swap Battery (EMSB) technology encourages the formation of a new ecosystem at the early of the supply chain, including technopreneurs and startups from manufacturers, suppliers, and distributors for commercialization. Swappable Batteries (SB), Electric Motorcycle (EM), and Battery Swap/Charging Station (BSCS) are key components of EMSB that have attracted the attention of supply chain players and government to find a thriving solution to enable faster adoption and diffusion of EMSB in Indonesia. Previously, the Center of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret (or CoE-EEST UNS) has developed SB, EM, and BSCS prototypes with limited systems to operate the EMSB. However, to transfer technological innovations and/or facilitate operations of the EMSB on a large scale, there are various challenges and problems with products, processes, innovations, and businesses that are required to be solved. There are five interventions/models that were proposed by CoE-EEST UNS, namely circular business for EMSB, innovation diffusion and adoption, technology readiness and economic benefits prediction, location-allocation for smart charging, and Internet of Things based decision support system for distributing EMSB, and the technical requirements for interoperable of EMSB. The interventions/models are seen as alternatives to accelerate the downstream of EMSB technology innovation, and then maximize the economic benefits of a green economy in Indonesia

Short Biography:

Wahyudi Sutopo is a professor in industrial engineering and Head of Industrial Engineering and Techno-Economics Research Group, Department of Industrial Engineering, Universitas Sebelas Maret (UNS), Surakarta, Indonesia. He is also as researcher for center of excellence for electrical energy storage technology (CoE-EEST), the president of the industrial engineering and operations management (IEOM) society for Indonesia's professional chapter, and Director, IEOM Asia Pacific Operation. His

educational background is the profession of engineer from UNS (2018); Doctor and Bachelor in industrial engineering from Institut Teknologi Bandung (2011 & 1999); and master of management science from Universitas Indonesia (2004). His research interests include supply chain engineering, engineering economy & cost analysis, and technology innovation & commercialization.

Dr Sutopo has completed research projects with more than 45 grants and carried out research projects funded by Institution of Research and Community Services - UNS, Ministry of Research and Technology / National Agency for Research and Technology, Indonesia Endowment Fund for Educational (LPDP), PT Pertamina (Persero), PT Toyota Motor Manufacturing Indonesia, and various other companies. He has written 4 text books and 7-chapter books and made 5 intellectual property rights (IPR) in the form of copyrights, and 3 patents. He has initiated to commercialize research outputs of UCE-EEST UNS related to energy storage technology and electric vehicle conversion through start-ups where he is one of the founders, namely PT Batex Energi Mandiri and PT. Ekoelektrik Konversi Mandiri. Dr Sutopo has published articles over 185 documents indexed by scopus with H-index 13. His email address is wahyudisutopo@staff.uns.ac.id.

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Dyah Lestari Widaningrum

Ground Control Station Design Optimization for Indonesian Operator Work Postures and Muscle Stimulation in Preparing the MALE Class UAV

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ABSTRACT

An Unmanned Aerial Vehicle (UAV) flies without human on board but its mission must be fully controlled by the man operator on-ground below. Thus, this paper showed adaptation in designing a proper work space for UAV operators to ensure the effectiveness of its aerial mission. A Medium Altitude Long Endurance (MALE) is a class of UAV that often characterized to have a long period of operation time. Preliminary assessment on the ground crews of the UAV found that they are exposed to a critical workload (i.e., push and pull of a heavy tool). To further analyze this problem, a prediction was carried out by creating Digital Human Modeling (DHM) of 5, 82, and 95 percentiles of sample population, and these DHM then analyzed using Rapid Entire Body Assessment (REBA). Six participants were measured to represent anthropometry data based on Standing and Reaching posture. The analysis is referring to several activities, for instance Task-1: lifting gas cans; Task-2:pouring the gas to the generator ; Task-3: swinging the hatch. Total REBA scores for Task-1 at ranging percentiles showed 11 to 12. Task-2 highlights at 5%ile the REBA scored up to 13, and the rest about 11. Task-3 describes the REBA score around 11 at all ranging of percentiles.

*All authors contributed equally to this research.

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CCS CONCEPTS

• **General and reference** → **Evaluation**; *Measurement*; Metrics.

KEYWORDS

UAV Ground Control Station, Work Posture, DHM, REBA

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1 INTRODUCTION

In aviation to answer the need of working on low safety flight condition, an Unmanned Aerial System (UAS) was built to reduce human interaction when operating the air vehicle. The truth is that on many occasion the human interaction is not reduced that much. Most of the time the pilot is just physically removed from the air vehicle cockpit and place on ground in the saver working condition, hence the name Unmanned Aerial Vehicle (UAV).

The station where operator can safely operate the UAV is known as a ground control station (GCS). While both parts are equally important, some studies suggest that a GCS is the core of system of a UAS [13] . The working condition in a UAS is similar with the one on manned system. While the incorporation of autonomous

systems brings potential to the improvements in operational safety, efficiency and effectiveness, it also adds several points of consideration on Human Factors [8].

Human conditions, such as fatigue, complacency, and stress, so important in aviation. These conditions, along with many others, are called human factors [3]. Ergonomics is also a part of human factors, the two terms sound like having different meaning, whereas both has been influenced by a slightly different set of circumstances of usage and context [2].

Another personnel related to the UAV beside pilot that also work on GCS is the ground crew. Its workload expands from installing or dismantling the GCS to maintaining and repairing GCS when needed. Despite the difference responsibilities, all personnel share the similar working environment within GCS, thus the safety and security of that personnel is equally important. A heavy load work is a recurrent activity for GCS ground crew, and most of that activity is a physical activity.

The GCS is designed to support monitoring activities and playing their roles in the mission for up to 24 hours, and it is planned to operate in a harsh environment (i.e., open-air within 12 hours of sun exposure and high humidity day and night). As the base of the mission role, the human factor aspects are considered as priority in design. Figure.1 Illustrates manufacturing process of MALE GCS.

Between high concentration and long work time, having a decent and well-designed GCS is beneficial for the operator. This work is addressing the relation between ground crew activity on the MALE class UAV GCS, so that the future GCS can be benefitted from better design analysis.

To assess whole-body postural MSDs and risks associated with job tasks, an ergonomic assessment tool called Rapid entire body assessment (REBA) [7] will be used. Since conducting human performance measurement is a high cost and a time-consuming process, to further improve the quality of the analysis and reduces the developmental cost and time, a simulation of ergonomics can be conduct in a virtual environment at an early design phase using a digital human modeling (DHM) software [9]. At this point DHM is offering vice versa, in contrast, its ability only supports the geometric dimensions and the biomechanical characteristics of humans [4].

It is difficult to compare publish data about work posture on GCS ground support activities. Previous works has been done related to the usage of REBA and utilization of DHM were working on a study literature on Qualitative Meta-Analysis of Digital Human Modeling and Cyber-Physical-Systems in Ergonomics 4.0 [10]. Other works related with DHM was for exploring design space on aircraft cockpit design [5], and preventing Work-Related MSD [12] using DHM on production lines [6]. This study aims to predict and investigate the work posture risk and its muscles stimulation during activities using digital human modeling and REBA analysis.

2 METHOD

2.1 Work activities screening

The work activities were chosen based on appraisal score criteria, for example: load carried during activity, temperature at work, and Posture. Table.1 shows workload during GCS mission without respect to the time duration. It can be assumed that work at ground support is riskier than in cockpit i.e., Action risk and hazard facing.

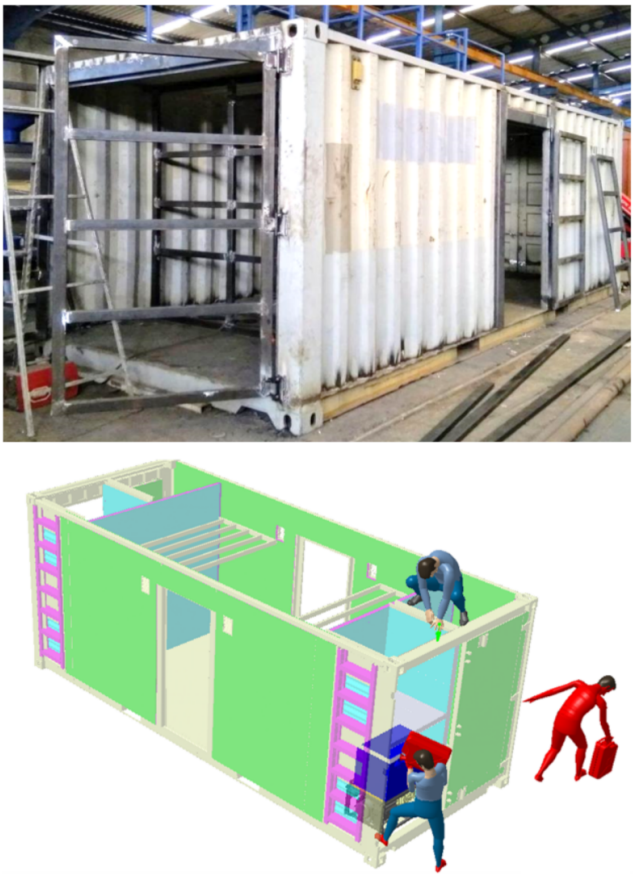


Figure 1: Exterior structural modification at LH side, STANG-4671 (2021) article U1703 describes Human factors aspect on GCS crew and operator at workplace shall perform their duties without unreasonable fatigue and less concentration

Table 1: Work appraisal score based on criteria: temp, load and posture

Work Item	Temp (C)	Load (N)	Posture
Cockpit			
Turn-on/off PC	23-25	<5	sitting
Input mission	23-25	<5	sitting
Monitoring	23-25	0	sitting
Ground support			
Open the side doors	35-40	130	standing
Climbing ladder	35-40	-	standing
Open hatch	35-40	97	squatting
Pull & push generator	35-40	135	standing
Lifting gas can	35-40	200	standing
Pouring the gas	35-40	200	standing

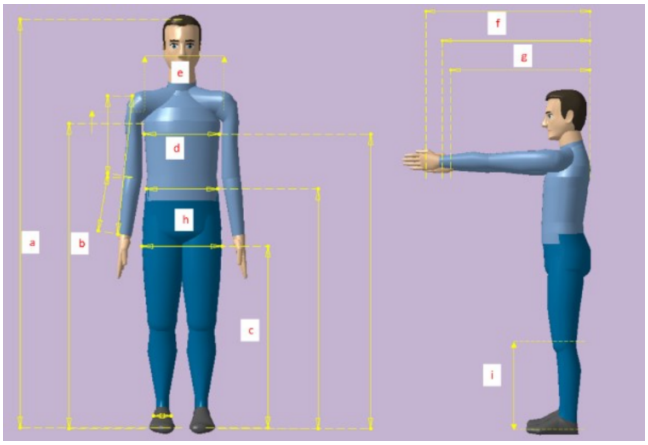


Figure 2: Human Builder on standing and reaching posture

2.2 Anthropometry fitting

After that, anthropometry data were collecting by summarized the whole data to mean data and deviation. To measures the spread sample of data distribution from the population, then, sample standard deviation is used. The more scattering out a data distribution means the data is far from zero [11]:

$$SD_{sample} = \sqrt{\frac{\sum |x+\mu|^2}{n-1}}. \tag{1}$$

Where $\sum$ is a "$sum\ of$", then "x" is a value of data set, "μ" is the mean data set, and "$n-1$" is the number of data points. Subsequently, the means stature parameter is compared with Indonesian stature anthropometry data, following the equation describes, where: X_p"$percentile$", "z" is a constant percentile concerned.

$$X_p = \mu + zSD. \tag{2}$$

In comparison, the population sample of anthropometry of Indonesian are provided as the reference by the Antropometri Indonesia. Therefore, the equation 1 and 2 can be executed (see details data antropometri 2022) [Recap of Indonesian Antropometry Data].

Body mass index (BMI) was used as second filter to determine whether the participant has ideal proportion (i.e. ratio of mass of muscle to fat). The details of BMI criteria of can be seen in WHO body mass index page [**?**].

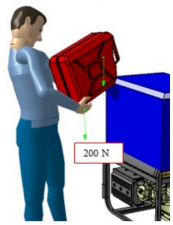
2.3 Digital human modeling

Figure.2. describes anthropometry data parameters measurement that cans be applied to generate digital human modeling (human builder). The parameters were grouped to two postures + addition: (a) standing and (b) reaching and (c) vision [5].

2.4 Posture analysis setting

REBA method was used as postural analysis. In general, REBA score is a combination of qualitative judgement with body limitation. The body limitation is based on the neck, trunk, leg, upper arm, lower arm, wrist and legs [6]. The task details are shown in Table.2. In addition, biomechanics and vision perspective was conducting to review REBA analysis results more detail. The vision preconditions were setup the parameter including: type: binocular, limits: horizontal, vertical mono and binocular, and distance vision punctum proximum and remotum ware set 50mm and the focus distance about 300mm respectively.

Table 2: Task description preparing GCS of UAV mission

Illustration	Task	Description	Load
	1. Lifting gas cans, setting to electrical generator	handhold	200N
	2. Pouring gas, setting to electrical generator	handhold	200N
	3. Swinging hatch hatch, setting on the GCS roof area	handhold	130N

3 RESULT

3.1 Anthropometry measurement

Table.3 describes the data collection of anthropometry measurement on standing and reaching posture. There are six criteria that measured on standing posture, for instance: stature, axilla, omphalion, acromion and hip. Whilst, thumb tip reach, wrist length and mid patella are categorized as reaching posture. Another criterion is body mass index. Since the criteria measured were scalar; it calculates to mean data and standard deviation data. Following example of anthropometry measurement experiment see Figure.3.

From the equation 2 it can be determined that GCS 50%ile operator is equivalent to 82%ile instead of Indonesian stature population. To sum up, the mean data were determined to be parameter to DHM. Then, the body mass index criterion (BMI) of "20" is chosen or comparable to height 170 cm with 52-58 kg profile (see in table.4).

Table 3: Anthropometry measurement of GCS ground support operator

	Stature (mm)	Axila height (mm)	Omphalion waist height (mm)	Chest breadth (mm)	Acromiun breadth (mm)	Thumbtip reach (mm)	Wrist length (mm)	Hip length (mm)	Midpatella (mm)	Weight (kg)
P-1	1720	1330	1000	380	420	790	670	360	490	80
P-2	1700	1320	1010	380	410	740	620	280	510	58
P-3	1700	1300	1000	400	440	810	700	450	480	115
P-4	1710	1270	950	400	430	680	610	350	520	95
P-5	1740	1360	1010	380	430	750	650	330	540	82
P-6	1710	1290	1010	240	390	690	600	270	530	48
mean	1713,3	1311,7	996,7	363,3	420	743,3	641,7	340	511,7	79,7
SD	13,7	29,1	21,3	55,9	16,3	47,5	35,3	40,6	21,1	22,2

Table 4: Participants Body mass index collection

	P-1	P-2	P-3	P-4	P-5	P-6
Stature	1720	1700	1700	1710	1740	1710
Weight	80	58	115	95	82	48
BMI	27	20,1	39,8	32,5	27,1	16,4
Criteria	Over	Normal	Obesity Level-2	Obesity Level-1	Over	Under

Figure 3: Anthropometry and BMI measurement of GCS operators regarding two postures standing and reaching; a) underweight, b) fit and c) obesity

3.2 Digital Human Modeling

The following example illustrates the anthropometry percentile comparison between Indonesian anthropometry sample in 2018 compared with measured GCS operator mean stature in 2022 (shown by Figure.4). In series, the statures are 5%ile = 1170 mm; 50%ile= 1688; 90%ile= 1870 mm and the red DHM of GCS 50%ile or 82% = 1713mm. From these DHMs profile, percentile 5%, 82% and 95% were selected for posture analysis.

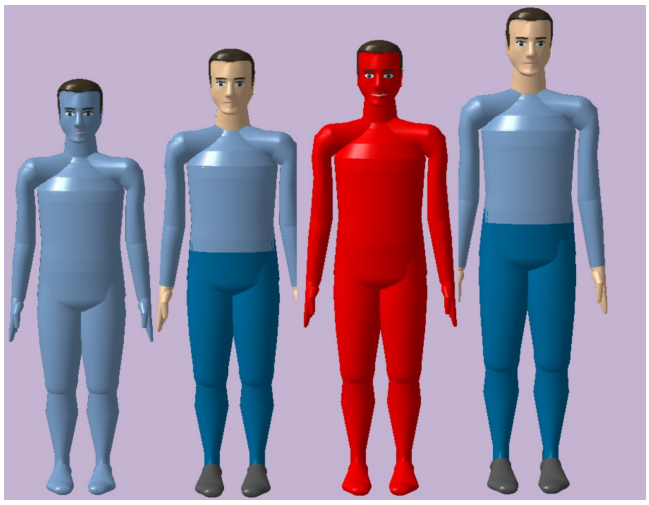


Figure 4: DHM operator result based on anthropometry percentile of 5, 50, GCS operator (82%ile) and 95%ile that processed using data measurement

3.3 Posture Analysis

All the DHM operator are working right-handed (RH)

3.3.1 Task-1: Lifting gas Cans. The critical stress and strain occur when DHM operator flexing at the maximum front reaches zone of

Figure 5: Predictive DHM when working Task-1 lifting gas cans posture analysis in superimposed sagittal view

him (Figure.5). Its posture needs to bend the trunk deeper, whilst, the CG (center gravity) of gas cans still far from the operator body CG. The movement of the task starts with half squatting- shifting weight behind the knees, then the shoulders abducting and the elbow LH elevating and the forearm extension. The REBA score of lifting gas cans shows at DHM 5%ile 95%ile and 82%ile posture 11 and 12 respectively. All indicates all the posture shall change now or immediately. The major risks are contributed by its load and trunk movement (see table.5).

Figure.6 illustrations the biomechanics of DHM 5%ile, 82% and 95%ile flexing the spine deeper about in series. While the head is extension and rotating 3.5° and 33° respectively. In contrast, 95%ile and 82%ile shall flexing, abducting and rotating more deeper than 5%ile. Muscles assessment is carried out to the critical load at squatting step, the thigh and leg were abducting and flexing in a half, where the posterior hip flexors concentric and abductors concentric. At this level, the hip, quadriceps and hamstring muscles are moving the whole mass.

At the step DHM grab the gas cans handle, shoulder abducting, and the elbow through the forearm extension and pronation. However, when the DHM starts to lift the gas, brachioradialis concentrically prone the palm then follows by triceps eccentric and biceps brachii concentric. To ease biceps work, the deltoid muscles eccentric to pull the shoulder and send signal to the brain to self-balancing between load and body center of gravity (cg), it describes in Figure.6 and 7.

3.3.2 Task-2: Pouring gas Cans to Generator. The task movement is emphasized on manual pouring the gas cans to the generator.

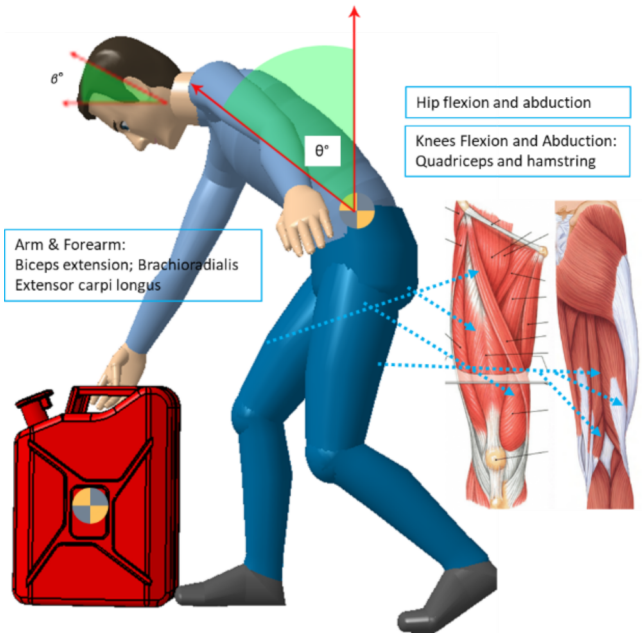


Figure 6: Full spine and lower limb step movement to move center of gravity behind the knees

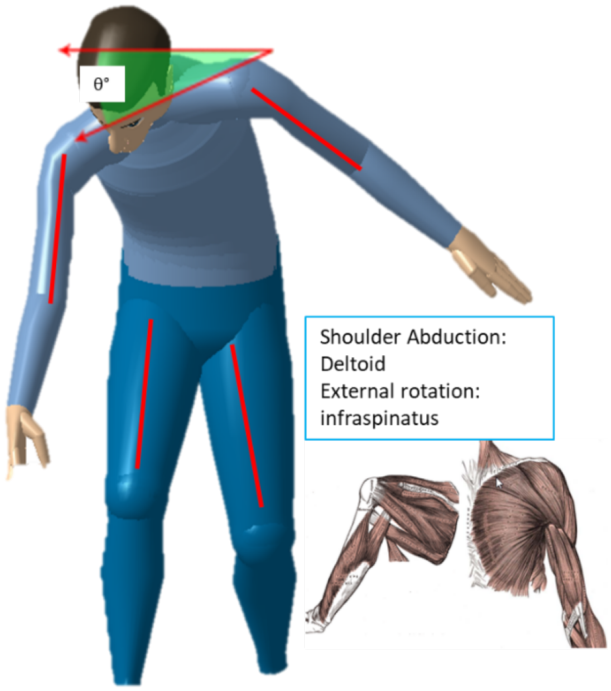


Figure 7: Upper limb muscles step movement when lifting the gas in general

Table 5: REBA Analysis for Common Working Lifting Gas to Generator (Task-1)

Percentile	Posture A	Posture B	Coupling	Force	Score	Activity score	Activity level
5%	10	5	1	2	11	-	(11)
82%	11	6	1	2	12	-	(12)
95%	11	6	1	2	12	-	(12)

Table 6: REBA Analysis for Common Working pouring gas to Generator (Task-2)

Percentile	Posture A	Posture B	Coupling	Force	Score	Activity score	Activity level
5%	10	9	1	2	12	1	(13)
82%	8	8	1	2	10	1	(11)
95%	8	8	1	2	10	1	(11)

Posture is standing and the full spine is extension to shift weight behind lumbar disc. The shoulders abducting, whilst the RH shoulder is elevating and the opposite do depression. The shoulder through elbows flexing to resist the load due to mass times gravity, see Figure.8. The REBA score at three DHM as follow 13, 11 and 11 respectively. Its analysis indicates the posture shall change now or immediately or in high risk, as shown Table.6.

The subsequent illustration (Figure.9) summarizes the work posture of DHM operator when pouring the gas to generator. The precondition of this posture are same foot and gas cans position, the DHM operator of 82% and 95%ile shows similar posture and movement instead of 5%ile.

Regarding the precondition above, the DHM 5%ile shows the shoulders are adducting and depressing movement at LH, meantime at RH the shoulder is elevating (see Figure.10). This movement is aimed to move then hold the load. The deltoid and clavicular muscles are instructing to move the shoulder; whereas biceps and triceps are controlling arm and forearm. However, the full spine is moving hyperextension to balance the load. At lower limb, to reinforce the load the thigh LH is flexing and abducting, then rotating lateral.

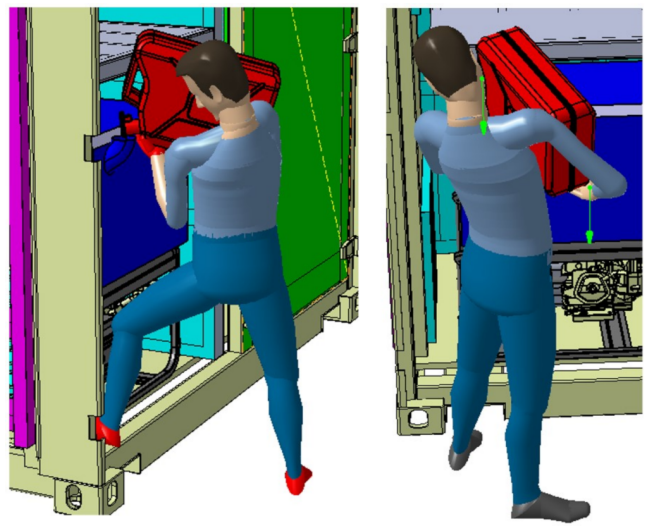


Figure 8: Pouring gas work posture to the electrical generator using DHM operator 5% and 95%ile

3.3.3 Task-3: Swinging Hatch on Roof. Figure.11 illustrates the third task of swinging the hatch on the GCS roof. The movement of the task starts with full squatting down - shifting weight behind the knees, then the shoulders adducting and the elbows relaxing into flexion. The REBA scores found that swinging the hatch at DHM 5%ile posture is very high-risk level to continue. Similarly, 82% and 95%iles showing of score 11 respectively (see Table.7). Its analysis indicates all the posture shall change now or immediately.

How muscles work perspective, DHM 5%ile flexing the spine deeper about 56.5°, while 82% and 95%ile are flexing the spine lesser about 53 deg. Consequently, to maintain the arm focuses on the handle, 5%ile shall flexing and rotating their head about 1.5° and -24.5° respectively (see Figure.12). In contrast, 95 and 82%ile shall flexing, abducting and rotating more deeper than 5%ile. Overall, the muscles movement of swinging hatch are similar to the lifting gas cans. The differences are highlighted on shoulder hyperadduction and full versus half squatting posture.

3.4 Vision Analysis

According to precondition method above, the DHM operator's visons are presented. The summarizes vision describe focus and distance when the DHM working on task-1 is shown in Figure.13, where at 82% and 95%ile the focus distance is far than 5%ile. All DHM neck were extension, then the splenius concentric do lateral left and rotation right.

Different case represents to pouring gas cans to generator task. The DHM 82% and 95% vision shows the perspective of gas can from above, in contrast, the 5%ile showing the opposite However, all DHM vision confirmed not effective due to the tank hole cannot be seen (Figure.14). To describe the movement, the neck flexing and the splenius eccentric. There are lateral right and rotation left.

Following case below shows similarities posture with task-2, contrary, the neck flexing and the splenius eccentric. There are lateral right and rotation left. The Figure.15. summarizes the vision focus at ranging DHM percentile during swinging the hatch.

Table 7: REBA Analysis for Common Working Swinging Hatch on Roof Area (Task-3)

Percentile	Posture A	Posture B	Coupling	Force	Score	Activity score	Activity level
5%	10	5	1	1	11	-	(11)
82%	10	5	1	1	11	-	(11)
95%	10	5	1	1	11	-	(11)

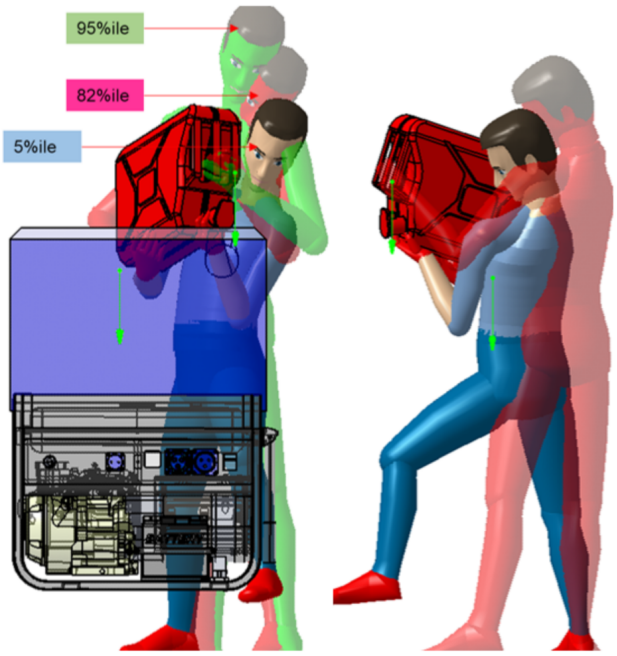


Figure 9: DHM operator working on Task-2 in superimposed frontal and sagittal view section

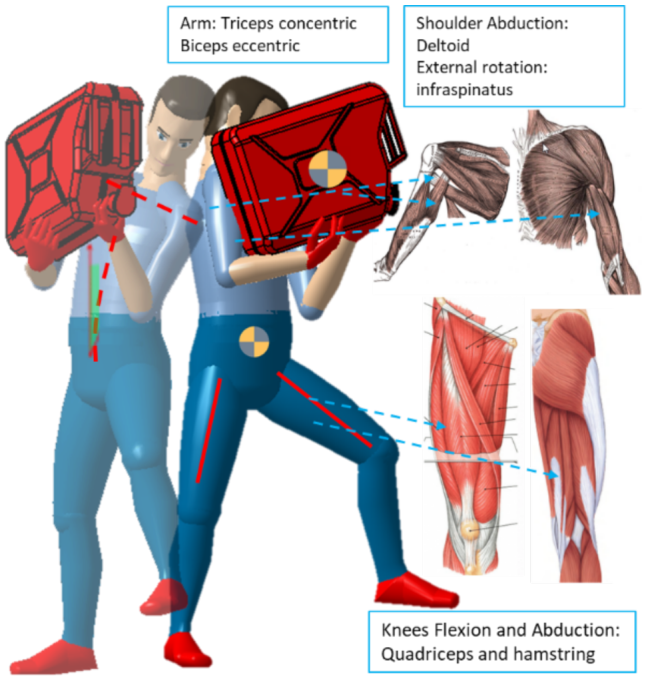


Figure 10: DHM operator 5%ile on how muscle work on task-3 lifting gas can

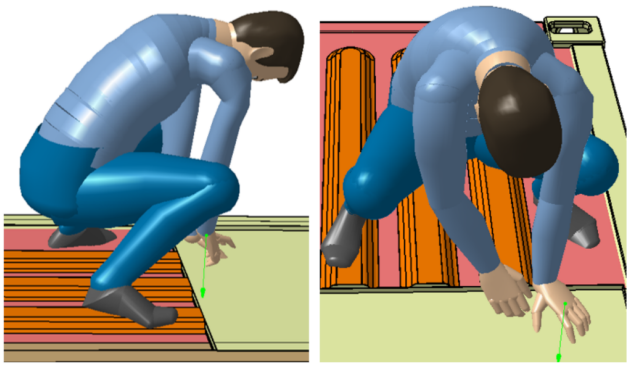


Figure 11: Swinging hatch posture analysis at 5% and 82%ile

4 CONSLUSION

The study indicates preparing UAV mission through task-1 to task-3 of ground control station using DHM has detrimental effect on ground support operator, for example: musculoskeletal disorder (MSD). Based on REBA scores combined with ranging of percentiles, All the tasks show inability to lower the risk by its posture, increase of the stress at upper and lower limb muscles due to far CG, and the vision clarity decreased when pouring gas. The higher percentiles the operator you selected means it can be riskier, or vice versa. From the perspective of how muscles work, there are coordination and combination of all muscles in every movement of our body not only about upper and lower limb.

Overall, according to DHM investigation, a technology interruption for helping operator doing their work on preparing UAV mission through GCS is saving two things: it is diminished changing the position immediately, and it is not necessary changing the GCS design.

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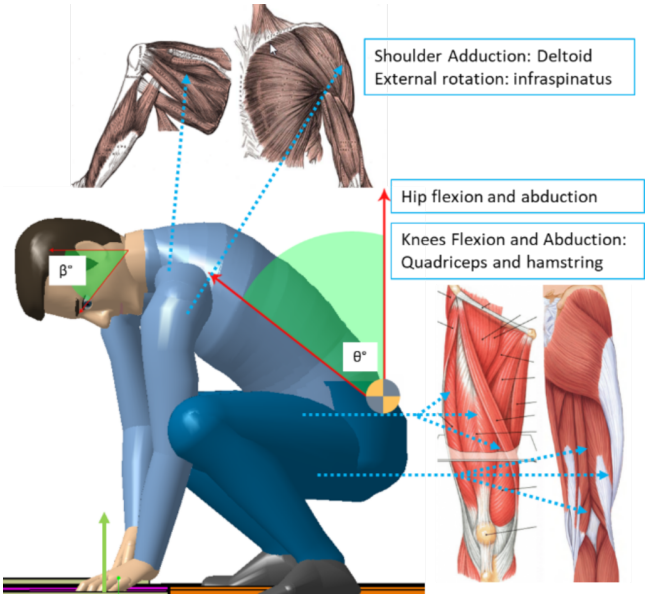

Figure 12: General muscles work analysis when swinging GCS hatch

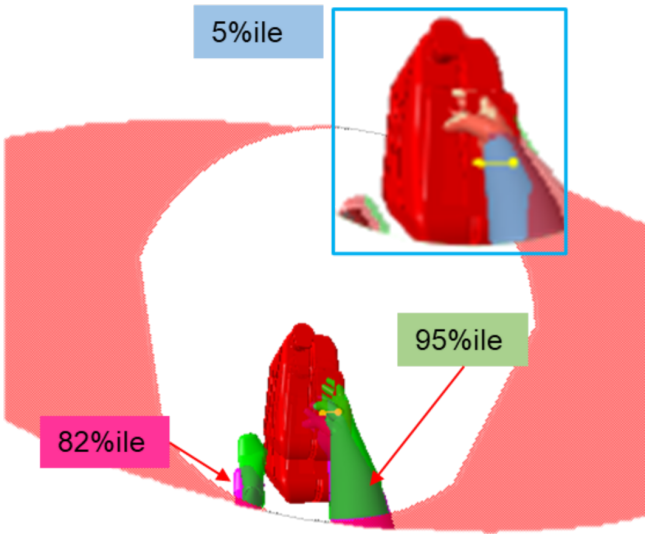

Figure 13: Vision area comparison of ranging DHM when lifting gas can

one of the result from the Research Proposal Program entitled "Desain Ground Control Station 4.0 untuk Medium Altitude Long Endurance Unmanned Aerial Vehicle Tahun Anggaran 2022" membered by the authors. Activity no. 6692:. "Riset Bidang Penerbangan dan Antariksa". in the category of "Topik Riset Teknologi Penerbangan" hosted by PRTP-ORPA. (BRIN Center for Aviation Technology Research)

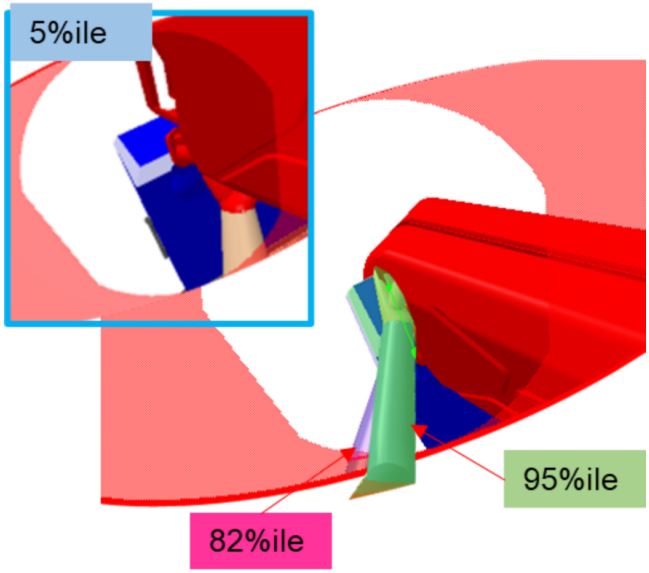

Figure 14: Blind spot vision comparison of ranging DHM when pouring gas to generator fuel hole intake

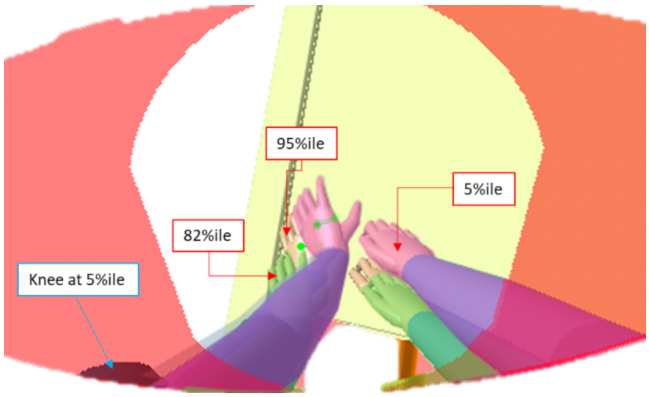

Figure 15: Summarized vision area of DHM percentiles (5%ile, 82%ile, and 95%ile) when do swinging hatch on GCS

REFERENCES

[1]]BMI [n. d.]. https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/body-mass-index
[2] 2004. *Human Factors for Engineers.* Institution of Engineering and Technology, Stevenage, England.
[3] Federal Aviation Administration. 2018. *Aviation maintenance technician handbook-general 2018: Faa-H-8083-30a* (2018 ed.). Aviation Supplies & Academics, Newcastle, WA.
[4] Heiner Bubb. 2019. *Why do we need digital human models?* Elsevier, 7–32.
[5] Julie Charland. 2019. Chapter 9 - Virtual Ergonomics by Dassault Systèmes. In *DHM and Posturography*, Sofia Scataglini and Gunther Paul (Eds.). Academic Press, 97–103. https://doi.org/10.1016/B978-0-12-816713-7.00009-X
[6] S. Hignett and L. McAtamney. 2000. Rapid entire body assessment (REBA). *Applied ergonomics* 31, 2 (2000), 201–205. https://doi.org/10.1016/s0003-6870(99)00039-3
[7] Fatemeh Jahanimoghadam, Azadeh Horri, Naimeh Hasheminejad, Naser Nejad, and Mohammad Baneshi. 2018. Ergonomic Evaluation of Dental Professionals as Determined by Rapid Entire Body Assessment Method in 2014. *Journal of dentistry (Shiraz, Iran)* 19 (06 2018), 155–158.
[8] Yixiang Lim, Alessandro Gardi, Roberto Sabatini, Subramanian Ramasamy, Trevor Kistan, Neta Ezer, Julian Vince, and Robert Bolia. 2018. Avionics Human-Machine

Interfaces and Interactions for Manned and Unmanned Aircraft. *Progress in Aerospace Sciences* 102 (2018), 1–46. https://doi.org/10.1016/j.paerosci.2018.05.002

[9] Charu M. Maurya, Sougata Karmakar, and Amarendra Kumar Das. 2019. Digital human modeling (DHM) for improving work environment for specially-abled and elderly. *SN Applied Sciences* 1, 11 (2019). https://doi.org/10.1007/s42452-019-1399-y

[10] Gunther Paul, Nils Darwin Abele, and Karsten Kluth. 2021. A review and qualitative meta-analysis of Digital Human Modeling and Cyber-Physical-Systems in Ergonomics 4.0. *IISE transactions on occupational ergonomics and human factors* 9, 3–4 (2021), 111–123. https://doi.org/10.1080/24725838.2021.1966130

[11] Stephen Pheasant. 2014. *Bodyspace: Anthropometry, ergonomics and the design of work: Anthropometry, ergonomics and the design of work.* CRC Press, London, England. https://doi.org/10.1201/9781482272420

[12] Somieh Rahimabadi, Narges Khanjani, and Hossein Mardi. 2012. The Prevalence of Musculoskeletal Disorders and their Related Factors in Workers of A Dairy Factory, Nishabur, Iran. *Health and Development Journal* 1, 2 (2012), –. arXiv:https://jhad.kmu.ac.ir/article_91161_7a0c52d9eb9b3fbfad5809f97937d38e.pdf https://jhad.kmu.ac.ir/article_91161.html

[13] Yingbo Zhou, Jingyun Hou, and Yi Gong. 2020. Research and Application of Human-computer Interaction Technology based on Voice Control in Ground Control Station of UAV. In *2020 IEEE 6th International Conference on Computer and Communications (ICCC)*. 1257–1262. https://doi.org/10.1109/ICCC51575.2020.9344892

Scaffolding Methodology Implementation for Training Program in an Engine Assembly Department of Indonesian Remanufacturing Company

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ABSTRACT

Remanufacturing is a form of circular economy implementation that is crucial to drive the sustainability development goals. PT. XYZ, one of the most extensive remanufacturing companies in Indonesia aims to improve its competitiveness and sustainability by focusing on their human resources aspect, especially on the competencies of assembly mechanics. The challenge occurred when the learning development lead time is time consuming, thus found an urgent need for its optimization. In order to dealt with the challenge, this research is conducted by adopting the Scaffolding Methodology model of which consists of four stages, namely focused instruction, guided instruction, collaborative learning and independent learning. The training program emphasized not only on the enhancement of the curriculum and the practical concept, but also its training location and the adoption of E-Learning. Moreover, the use of scaffolding method as gradual release of responsibility framework has been deployed, as well as knowledge conversion in the form of assembly collaboration and re-layout of assembly lines. Finally, this study has succeeded in developing an integrated training program that able to generate a significant reduction in preparing mechanic's competencies.

CCS CONCEPTS

• :; • **Social and professional topics** → Professional topics; Management of computing and information systems; System management; Centralization / decentralization;

KEYWORDS

Knowledge Management, Scaffolding Methodology, Training Program, E-Learning, SECI

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1 INTRODUCTION

The heavy equipment business is one of the most promising businesses in Indonesia. Almost all industrial sectors require heavy equipment. Heavy equipment has a high investment value. To maintain machine performance according to the manufacturer's recommendations, components have to be overhauled regularly. As a form of after-sales service, heavy equipment distributors build remanufacturing facilities to overhaul components.

Remanufacturing is a subset of manufacturing. Remanufacturing is also a form of circular economy that is in line with the G20 agenda and the Sustainable Development Goals (SDGs) agreed by world leaders, including Indonesia. Remanufacturing is very important to maintain the sustainability of the company, industry & ecosystem. Definition of remanufacture, recondition, and repair according to Ijomah [1] and Ijomah et al., [2].

Remanufacture**:** the process of restoring the performance of a used product, as minimum as OEM specification from customer's perspective and provides a product warranty at least equal to that given to new products.

Recondition: the process of restoring the performance of a used product for satisfactory working condition, the result possibly under OEM specification. Generally, the products have less warranty than that given to new products.

Repair: the repair process is only a correction of certain errors or damage to products. Generally, repaired products quality is lower than remanufactured and recondition. When a repair product has a warranty, it is usually less than that given to a new product and it does not cover the entire product but only the parts that were repaired.

PT. XYZ has a competitive advantage in the form of remanufacturing facilities with cutting edge technology, large production capacity, full technical support and a good supply chain from a highly adaptive mother plant factory. To optimize these potentials in generating outcomes, these competitive advantages have to be support with adaptable and agile human resources, especially in term of competency. One of the critical aspects is the engine production's assembly mechanics. This research improves existing training program which is required a high learning lead time into that can be absorbed in a faster time.

2 LITERATURE REVIEW

2.1 ADDIE Model

The ADDIE model is one of the methodologies for developing a systematic learning program that commonly used in effective problem solving and according to needs and characteristics [3]. ADDIE model stands for the stages of the development process itself, namely Analyze, Design, Develop, Implement, and Evaluate.

The analyze phase is the first phase where data collection and analysis related to performance and needs are carried out. The design phase focuses on relevant activities, which are selected based on existing conditions. In the Develop phase, details and technology integration carried out into validated designs and illustrations that are going to be used to achieve the objectives of this program. After develop phase is done, the alternatives are implemented in implement phase, and the reviewed in the evaluation phase to ensure the appropriate results are obtained at the end of the program.

2.2 Scaffolding Method

The scaffolding method refers to the gradual release of responsibility instructional framework, which purposefully transforms the cognitive load from instructor-as-model, to a collaborative responsibility with learner, then to independent practice by the learner [7].

2.3 Knowledge Management

Knowledge management is an attempt to increase the utilization of knowledge through a system of recording, sharing information, and managing it in an organization. The use of this approach aims to complete certain targets and this approach is able to increase organizational productivity with the right strategy [4].

2.4 Type of Knowledge

There are two types of knowledge that are generally recognized in the concept of knowledge management, namely explicit knowledge and tacit knowledge [5].

Explicit knowledge is a type of formal knowledge that can be articulated and expressed in numbers, letters and pictures into a universal fact. Where people who have no previous experience can still understand easily [5].

Tacit Knowledge, on the other hand, cannot be easily stated, because it is obtained by someone through things such as experience or point of view and all of this stick in the person's head [5].

2.5 Knowledge Conversion

In knowledge management, explicit knowledge and tacit knowledge can interact with each other through a system called knowledge conversion. Knowledge conversion is able to expand the quality and quantity of both knowledge through the conversion and combination of the two. There are four types of knowledge conversion, namely socialization, externalization, internalization, and combination [6] also known as SECI model, as can be seen in Figure 1.

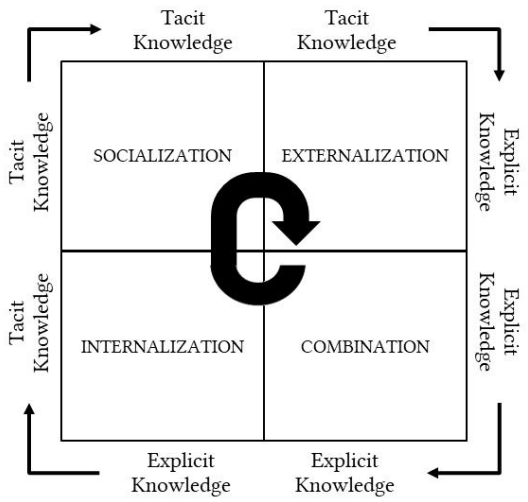

Figure 1: Knowledge Conversion [6]

3 RESEARCH METHODOLOGY

This research uses scaffolding method which is consisted in the development stage of ADDIE model. Specifically, under the development of training model process as shown in Figure 2 below.

4 TRAINING PROGRAM DESIGN & DEVELOPMENT

In order to have an adaptive and agile human resource, the company seeks opportunity for improvement in existing training program design. Not only a faster training program design, but it also has to be standardized both in lead time and quality. The company in parallel designed a more structured training program. For a better result the company will use scaffolding method as blended learning and gradual release of responsibility framework, since this method provides for a supportive learning environment and an actively engage learning process. The scaffolding method can be seen in Figure 3. Scaffolding methodology introduced by Fisher and Frey [7] emphasized more to the transition of learning process from teacher responsibility focus to student responsibility focus. By using this methodology, mechanics will go through cycle consists of focused instruction, guided instruction, collaborative learning & independent learning.

4.1 Identify Competency Development Lead Time

Training program designed by the company with expected target can be finished before twelve months, so the company can fill the competency gap during the year to catch up and fulfill customer demand. In the implementation, training program finished in twelve months. This long learning lead time makes the development become irrelevant with the company needs. Identification of competency development lead time shown in Table 1

Table 1: Identification Competency Development Lead Time

Competency Development Activity	Lead Time	Remark
Individual Development Plan (IDP) Input	1	
Mechanic registration & IDP mapping		
Create IDP mapping list		
Accept training program	2	
Accept annual training schedule		
In-Class Training execution	1	
In-Class Training certification	2	Training duplication & Waiting instructor
Register for gathering experience		
Gathering experience execution	6	Waiting component for assembly
Gathering experience certification	1	
Total Lead Time	12	

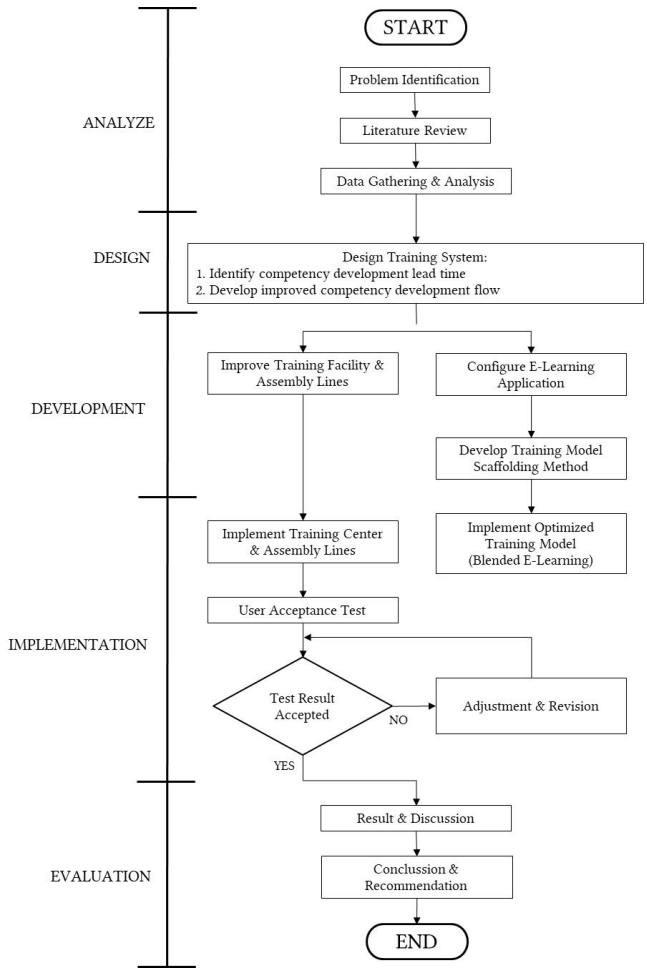

Figure 2: ADDIE Model [3]

4.2 Design and Development

The design and development of the training program will be focused in two aspects that have opportunity for improvement. The first is in-class training (Theoretical Aspect) and the second is gathering experience training (Practical Aspect).

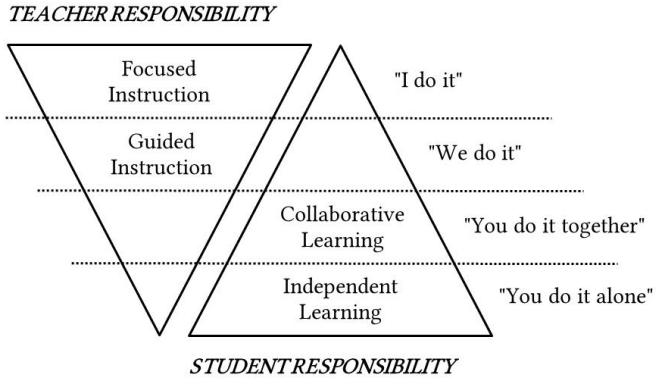

Figure 3: Scaffolding Methodology [7]

4.2.1 Theoretical Aspect. Two issue happened during in-class theoretical training execution are waiting for instructor and training material duplication. Related to waiting instructor problem, E-Learning application will solve the issue. Since mechanic will no longer dependent on instructor availability and both mechanic and instructor will have a flexible time to conduct training. Videos of work process and procedure, expert sharing video, and other videos applied in E-Learning will work as knowledge conversion to accelerate the mastering process. E-Learning dashboards consist of four major information. First, is the course schedule, which contains the ongoing and incoming training program. Second, is the current progress of the conducted course followed by the assigned mechanic. Third, it listed the registered certificates. Fourth, is the achievement of overall individual development program. Visualization of the dashboard is specifically shown in Figure 4.

Regarding the training material duplication, 50% of training material consists of refreshment material from last training. It cost half of the training time only for refreshment. This will be rejuvenating by changing the refreshment materials with pre-test and post-test, so the understanding can be measured and filled during the training.

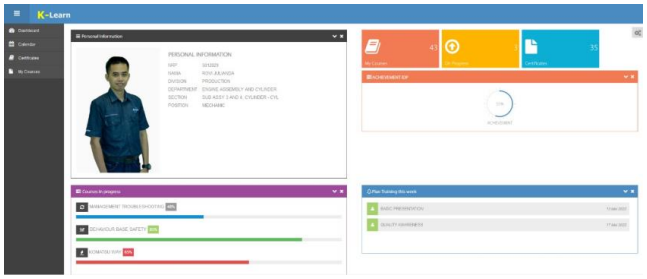

Figure 4: Application

Figure 5: Training Facility with Multimedia

4.2.2 Practical Aspect. Gathering experience or practical training often faces problem with the readiness of component for assembly. Since demand is very high, so most of components that available are prioritized to use for production and sales not for training. The development of practical training facility which have multimedia facility, spare parts and subcomponents practical training shown in Figure 5, will solved the issue. With low investment and without interrupting the production and sales, practical training can be done in this new facility. In addition, re-layout of assembly lines based on mechanic competency and collaboration assembly between senior and junior mechanic will act as knowledge conversion, that will fasten the gathering experience process. Re-layout of assembly line can be seen in Figure 6 and collaboration process shown in Figure 7.

5 RESULT

After the new training program developed and implemented, it is reviewed to measure the difference. Measurement is focused on competency development lead time before and after new training program implemented. Comparison result of competency development lead time before and after new training program implemented can be seen in Table 2. Based on Table 2, it can be seen that lead time successfully reduced from 12 months to 5 months or equal to 60% reduction.

6 DISCUSSION

Although the research is limited to engine production assembly, the design concept based on the ADDIE model can be implemented by other section or department in the company. Scaffolding method as gradual release of responsibility framework has different concept from ADDIE model but it is able to support the implementation to become more structured.

Focused Instruction and lesson purposed is a significant part of the scaffolding method. Through training material rejuvenation, implementation of E-Learning and online instructor, mechanic can have a faster overview regarding to their training and set up clear lesson purposed of the training.

Guided Instruction takes place and become better with the implementation of new training facility that have multimedia facility, spare parts and subcomponents practical training, and supported offline by instructor.

Collaborative Learning is conducted and become more impactful after assembly line are re-layout based on mechanic competencies.

Independent Learning are gain by mechanic as the ultimate goal. Mechanics become more creative, not dependent on others, and have lower learning lead time.

7 CONCLUSION AND RECOMMENDATION

To maintain competitiveness and sustainability, the company required adaptability and agility. In terms of developing agile human resources, the new training programs shows that it can be absorbed effectively by assembly mechanics with a lower learning lead time while maintaining the quality of work according to standards. The new training program combines activities of changing the pattern of competency development, rejuvenating learning materials, making E-Learning, re-layout assembly line and practical concepts, the use of scaffolding method and knowledge conversion. The new training program was able to lower the learning lead time from twelve months to five months (-60%).

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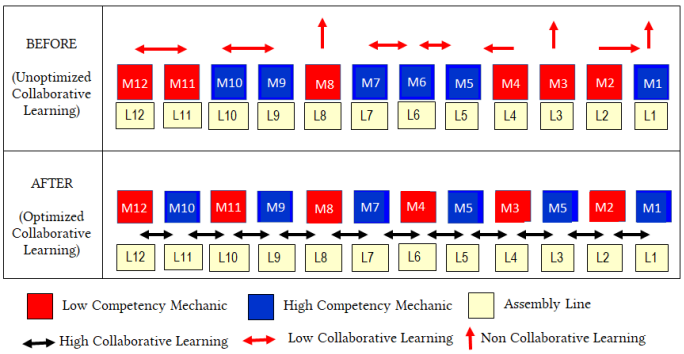

Figure 6: Re-layout of Assembly Line

Table 2: Result of New Training Program

Competency Development Activity	Lead Time	
	Before	After
Individual Development Plan (IDP) Input	1	1
Mechanic registration & IDP mapping		
Create IDP mapping list		
Accept training program	1	1
Accept annual training schedule		
In-Class Training execution	1	1
In-Class Training certification	2	1
Register for gathering experience		
Gathering experience execution	6	
Gathering experience certification	1	1
Total Lead Time	12	5

Figure 7: Collaboration Assembly

accepted me as one of their students and made me feel again the beautiful days of college.

REFERENCES

[1] Ijomah, Winifred Louissa, 2002. A Model-based Definition of the Generic Remanufacturing Business Process. PhD Thesis, Plymouth University from https://pearl.plymouth.ac.uk/handle/10026.1/601
[2] Ijomah, Winifred Louissa, Childe, Steve, McMahon, Chris, 2004. Remanufacturing: a key strategy for sustainable development. In: Proceedings of the 3rd International Conferenceon Design and Manufacture for Sustainable Development. Cambridge University Press. http://dx.doi.org/10.1016/j.buildenv.2006.10.027
[3] Aldoobie, Nada. (2015). ADDIE Model. American International Journal of Contemporary Research. Vol. 5, No. 6; December 2015. University Of Northern Colorado. Retrieved from: http://www.aijcrnet.com/journals/Vol_5_No_6_December_2015/10.pdf
[4] Poh Kiat Ng, Gerald Guan Gan Goh, Uchenna Cyril Eze, 2009. Knowledge Management: A case study of KM's role in a semiconductor manufacturing firm. International Conference on Quality, Productivity and Performance Measurement (ICQPPM'09).
[5] Kimiz Dalkir, 2005. Knowledge Management in Theory and Practices. Burlington: Elsevier. https://doi.org/10.4324/9780080547367
[6] Ikujiro Nonaka, Ryoko Toyama, Noboru Konno. 2000. SECI, Ba, and Leadership: Unified Model of Dynamic Knowledge Creation. Long Range Planning, pp. 9-10. https://doi.org/10.1016/S0024-6301(99)00115-6
[7] Douglas Fisher, Nancy Frey. 2008. Better learning through structured teaching: A framework for the gradual release of responsibility. Alexandria, VA: Association for Suspension and Curriculum Development.

Assessment Risk Ergonomic in Painting Industry using Ergo-FMEA

Assessment Risk Ergonomic in Painting Industry using Ergo-FMEA

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ABSTRACT

Generally, painting activity in industry is divided into 5 main processes namely cleaning, drying, painting, coating, and final process of drying. These activities are mainly implemented manually which bring high posture risk for the operators. This research is aimed to analyze ergonomic risk in painting industry by utilizing Ergo-FMEA (Failure Mode and Effect Analysis) methodology. Research stage is commenced by starting with job analysis, identification, ergonomic risk valuation and analysis, and improvement design to minimize risk. Risks are identified based on six risk categories namely horizontal distance, vertical distance, position, movement, environment, and performance. Identification results revealed 14 risks of work posture faced by operators. Activities that produce the highest risk are manual product moving and manual product lifting. These risks often lead to muscle pain, twisted joints, and back injury. The proposed improvements to minimize these risks are wire cart work facility design, workplace layout process costing improvement, and SOP of safe manual product lifting. This improvement proposal is expected to minimize the risk of posture on painting operators.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **HCI design and evaluation methods**; • **User studies**;

KEYWORDS

Ergo-FMEA, ergonomic risk, manual handling activity, painting

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1 INTRODUCTION

Generally, painting activity consists of five work process namely cleaning, drying, coating, painting, drying processes. These activities are conducted for 7 hours a day with high production target and precision. Initial problems indicated related to ergonomic risks in painting industry are manual product lifting risk from one place to another with repeated non-ergonomic movement and work position.

Risks are probable events that may occur, with potential for loss, which may arise from current or future activities [1]. Risks are inevitable but can be minimized [2]. The main risk factor of physical posture includes standing on a long period of time, not seating and resting, kneeling, bowing, neck bending, head rotating and bending, and also bending upper and lower areas of shoulder to practice certain works [3]. Exposure on these factors can cause various work complication and injuries such as respiratory disease, musculoskeletal, disorders (MSDs), physiological disorders, and cancer [4].

This research is aimed to analyze ergonomic risk occurs during painting process by utilizing Ergo-FMEA approach. Failure Mode and Effect Analysis (FMEA) has been utilized as a systematic method to identify risk of work procedure and environment on pharmacology companies [1]. [5] have been implemented DMAICR (Define, Measurement, Analysis, Improvement, Control, Risk) to analyze ergonomic risks. [6] utilizes FMEA and Risk Priority Number to evaluate ergonomic risks. [7] conducted methodology on risks analysis by a combination of two Lean Manufacturing practice. This approach shows chances to integrate work health and safety with performance improvement process and problem analysis methodology. Job analysis is an integral part of risk controlling program because it includes work procedure and necessary tools. Based on job analysis, activities with potential of danger will be revealed. Job analysis includes (1) Identify the Job, (2) Describe the Workers, (3) Describe the Work Schedule, (4) Determine Production (Work Pace) Information, (5) Describe the Job Rotation Plan [8]. This research is expected to be able to produce risk mapping on painting industry and to suggest work method and facility improvement designs to minimize ergonomic risks.

2 METHODS

This research is designed by using Ergo-FMEA (Failure Mode and Effect Analysis) approach with the following steps:

1. Job analysis through observation and interview.
   a. Identification of painting process sequence
   b. Work area physical environment
   c. The number of operators
   d. Work hour and work rotation
2. Categorization of ergonomic risks in painting area refer to risk classification [7]. Risk is divided into 6 category namely horizontal distance, vertical distance, position, movement, environment and work quality.
3. Identification of ergonomic risks that include risk, causes of risks, center of risks, risk types, and the probable location of risk.
   a. **Center of risk** which includes material handling tools operated by operators in painting area, environment, and machinery.
   b. **Risk types**, divided into two types of risk namely internal risk that connected to painting area and external risk that connected to areas outside of painting area.
   c. **Probable location of risk**, probable location of risk in painting area includes cleaning, drying, coating, painting, and final drying areas.
4. Ergonomic risk measurement is conducted with 3 dimensions namely severity, occurrence probability, and detectability. Measurement is conducted with scale of 1 to 10. Multiplication of severity, occurrence, and detection will produce Risk Priority Number (RPN). Risk measurement is conducted by internal source of companies that has experience and expertise on painting production process.
5. Improvement proposal will be provided based on risk analysis results.

Data collection activities were conducted through observation and interview procedures as follow:

1. Direct observation on work process in painting area, observing environmental condition around painting area, work hour, operator condition, and identification of ergonomic risks on painting activities.
2. Interview with operators and experts to gather data to conduct painting job analysis, identification, and risk analysis requirements.

3 RESULTS

3.1 Work Activity in Painting Area

Work activity on painting area conducted by operators is divided into 5 main processes namely cleaning, drying, coating, painting, and final drying. Each process is followed by moving activity before and after the conduction. Activities and movements conducted are described in Table 1. The number of painting area workers at PT. Braja Mukti Cakra has 18 employees for the entire work shift with the company's working hour arrangements applying to 3 work shifts, namely Office hours, shift 1, shift 2, and shift 3 with 8 active working hours each on weekdays, Monday to Friday. Friday. Meanwhile, on Saturdays, only 1 work shift applies.

The condition and environment of the Painting area is quite good. The painting area has been set using the 5Rs, namely Ringkas, Rapih, Rawat, Rajin, Resik (Concise, Neat, Treat, Diligent, and Clean). Lighting from the sun utilizes light that penetrates through the roof of the building area because the work is carried out during the day. The highest temperature recorded was 32 °C, the noise level in the painting area was at a value of 80.7 dBA while the threshold value was 85 dBA. Air circulation on the floor using ventilation which is placed at several points of the building. However, the air exchange inside is still quite hot and stuffy.

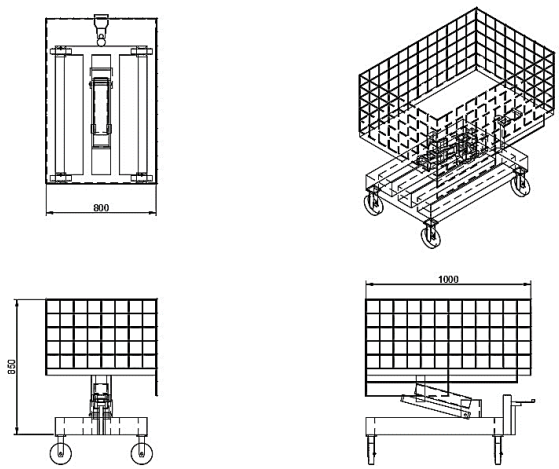


Figure 1: Details of the wirecart repair plan

Risk is divided into six risk categories, namely, Horizontal Distance, Vertical Distance, Position, Movement, Environment, Work Quality. The identification of work posture risks from each process activity is divided according to the risk category column into several more specific risks. Table 2 shows the work posture risk categories of each process activity, risk specifications and explanations.

Identification results through observation and interview on production unit can be seen in Table 3.

3.2 Ergonomic Risk Measurement

The stages of the ergonomics risk measurement model using the FMEA method is implemented on a number of stages namely determining the severity of the impact or consequences of an ergonomic risk (Severity), determining the level of ergonomic risk causes (Occurrence), detecting the cause of failure mode (Detection). The results of measuring the Severity, Occurrence, and Detection levels of each risk will later be used in calculating the RPN (Risk Priority Number).

3.3 Ergonomic Risk Management

After Ergonomic risk management model is implemented to minimize the occurrence or impact of ergonomic risks as shown in Table 4. Based on the results shown in. Table 5 shows ergonomic risk management model.

Details of the wirecart repair design can be seen in Figure 1, the purpose of the wirecart is to reduce the bending position of the operator and this wirecart can also lift a large load of up to 500 kg.

Table 1: Work Process Stages in Painting Area

Processes	Figure	Description
Cleaning		Before cleaning, operators move 4kg of disc brake from wire cart into certain place by lifting it. Disc brake cleaning is conducted by using brush and soap.
Drying		Operators move the disc brake from cleaning area to drying area by hand.
Coating		Coating process is conducted while standing. One hand is holding the coating spray meanwhile the other hand holds the product. After the process the product is placed on certain place with long hand reach.
Painting		Painting process is conducted with slightly bending posture, one hand is holding spray gun with tight grip.
Final Drying		Drying process is conducted by using oven. Operator position is bending with lowered head when placing disc brake.

4 CONCLUSION

Based on the research that has been done, there are 14 risks that may occur to the operator when working on the work process in the painting area. The highest risk occurs in manual moving and lifting activities. The causes of these risks are lack of knowledge of correct lifting techniques, inappropriate workplace layout, short wirecart sizes and loads that must be lifted by the operator. This risk will have an impact on the comfort and health of the operator while working.

The design improvements resulting from this research are (1) making SOPs on manual product lifting techniques, (2) designing work facilities in the form of wirecarts that can facilitate manual handling activities, (3) designing Workplace layouts in the coating process and adding a table to place WIP (work in process).

REFERENCES

[1] Akbari, J. *et al.* 2014. Macro-ergonomic risk assessment with the relative stress index method in textile industry. International Journal of Environmental Health Engineering. 2, 6 (2014), 12–17. DOI:https://doi.org/10.4103/2277-9183.131803.

[2] Kolgiri, S. *et al.* 2016. Literature Review on Ergonomics Risk Aspects Association to the Power Loom Industry. Journal of Mechanical and Civil Engineering. 13, 1 (2016), 56–64. DOI:https://doi.org/10.9790/1684-13135664.

[3] Mohamadinejad, A. *et al.* 2019. Risk Identification and Risk Assessment Using Failure Mode and Effect Analysis in a Textile Industry. Caspian Journal of Health Research. 4, 3 (2019), 60–65. DOI:https://doi.org/10.29252/cjhr.4.3.60.

[4] Motamedzadeh, M. *et al.* 2021. Ergonomic risk factors and musculoskeletal disorders in bank staff: an interventional follow-up study in Iran. Journal of the Egyptian Public Health Association. 96, 34 (2021), 1–10. DOI:https://doi.org/10.1186/s42506-021-00097-8.

[5] Dos Santos, E.F. *et al.* 2017. Failure mode and effect analysis (FMEA) as a model for accessing ergonomic risk. Occupational Safety and Hygiene V - Proceedings of the International Symposium on Occupational Safety and Hygiene, SHO 2017. (2017), 7–12. DOI:https://doi.org/10.1201/9781315164809-3.

[6] Dos Santos, E.F. and Dos Santos Nunes, L. 2017. Methodology of risk analysis to health and occupational safety integrated for the principles of lean manufacturing. Advances in Intelligent Systems and Computing. 487, (2017), 349–353. DOI:https://doi.org/10.1007/978-3-319-41688-5_32.

[7] Santos, E.F. and Lima, C.R.C. 2012. DMAICR in an ergonomic risks analysis. Work. 41, (2012), 1632–1638. DOI:https://doi.org/10.3233/WOR-2012-0364-1632.

[8] Yesmin, T. *et al.* 2013. Assessment of worker safety in a pharmaceutical industry using FMEA. Management science letters. 3, (2013), 55–64. DOI:https://doi.org/10.5267/j.msl.2012.11.005.

Table 2: Identifying Work Posture Risk Categories

No.	Risk Category	Definition	Risk Specification	Identification
1	Horizontal Distance	The risk is caused by the horizontal distance from the back of the body to the tip of the middle finger that reaches the work object.	Move products manually	The risk of horizontal spacing occurs in moving the product manually.
			Pick up the product manually	The risk of horizontal distance that occurs in picking up the product manually.
			Cleaning the product using a brush manually	The risk of horizontal spacing that occurs in cleaning the product using a brush manually.
2	Vertical Distance	The risk posed by the vertical distance from the floor to the top of the head when standing that reaches the work object.	Lifting the product manually	The risk of vertical distance that occurs when lifting the product manually.
			Incorrect product load lifting method	The risk of vertical distance that occurs in the wrong product load lifting method.
			Heavy product load to be lifted.	The risk arising from the vertical distance occurs in the product load that must be lifted.
3	Position	Risks that arise from the position of the body, head and limbs (hands and feet) both in the relationship betweenthe body parts that are not ergonomic.	The position of bending forward when working on the painting process.	The risk posed in a non-ergonomic position occurs in a forward bending position when working on the painting process.
			Bending forward position when picking up products on Wirecart.	The risk posed by an unergonomic position occurs in the forward bending position when picking up the product on the Wirecart.
4	Movement	Risks posed by non-ergonomic work movements	Wrist rotation in grasping objects.	The risks posed by non-ergonomic movements such as wrist rotation in grasping objects are carried out continuously.
			Movement of the arm when placing the product.	Risks posed by non-ergonomic movements such as arm movements when placing the product.
			Movement of the head up or down when lifting weights.	Risks posed by non-ergonomic movements such as head up and down when lifting weights.
5	Environment	The risks arising from the work environment and all its factors can harm the health of workers if not managed properly.	The pungent smell of Paint Painting in the Painting area.	The risk posed by the work environment in the painting area is the pungent smell of paint in the painting area.
			Hot air temperature.	Risks arising from the work environment in the painting area in hot air temperatures.
			Operators are less thorough or have difficulty seeing the object being worked on.	The risk posed by the work environment is that the operator is less thorough or has difficulty seeing the object being worked on.
6	Work quality	The risk arising from the quality of the operator's work which can be measured from the level of efficiency & effectiveness of an employee in doing a job.	Excessive workload.	The risk posed by the decline in the quality of workers due to excessive workload.

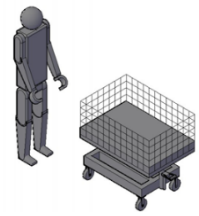
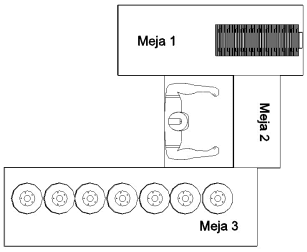
Table 3: Ergonomic Risks Identification in Painting Area

Risk Categories	Risk Specifications	Causes	Risk Center	Risk Type	Probable Area of Risk
Horizontal Distance	R.1.1. Moving product manually.	Automatic machine is not functioning.	Machine	Internal	Painting area on drying process.
	R.1.2. Picking product manually.	Automatic machine is not functioning.	Machine	Internal	Painting area on coating process.
	R.1.3. Cleaning product manually with a brush.	Automatic machine is not functioning.	Tools	Internal	Painting area on cleaning process.
Vertical Distance	R.2.1. Lifting product manually.	Automatic machine is not functioning.	Machine	Internal	Painting area on cleaning process.
	R.2.2. Unsafe Product Weight Lifting method.	Lack of knowledge regarding safe technique to lift large materials.	Human	Internal	Painting area on cleaning, painting and final drying processes.
	R.2.3. Heavy materials of product that must be lifted.	Lack of material handling.	Tools	Internal	Painting area on cleaning, painting and final drying processes.
Position	R.3.1. Forward bending position when lifting product in wire cart.	Uneven wire cart position.	Tools	Internal	Painting area on cleaning process.
Movement	R.4.1. Wrist twisting while holding object.	Heavy load on spray gun.	Tools	Internal	Painting area on painting process.
	R.4.2. Wrist movement during product placement.	Inaccurate Work Place Lay Out.	Human	Internal	Painting area on coating process.
	R.4.3. Upward and downward head movements while lifting weights.	Product weight.	Machine	Internal	Painting area on final drying process.
Environment	R.5.1. The smell of paint in painting area.	Indecent air circulation.	Work environment	Internal	In all painting area.
	R.5.2. High temperature.	Operators working in high temperature area namely oven, under the sun.	Work environment	External	In all painting area.
	R.5.3. Operator is not careful enough and often find it difficult to see the object.	Lack of lighting.	Work environment	Internal	In all painting area.
Work Quality	R.6.1 Excessive workloads.	Too many workloads and high number of manually conducted works.	Machine	Internal	In all painting area.

Table 4: Ergonomics risk measurement in painting activities

Risk Specification	Impact	Implemented Risk Control	D	O	S	RPN
R.1.1.	Causes muscle inflammation and sprains.	Trials are carried out on automatic machines regularly.	2	10	8	160
R.1.2.	Workers have the potential for injury to the shoulders, hands, wrists or other exposed parts of the body.	Trials are carried out on automatic machines regularly.	2	10	3	60
R.1.3.	Causes pain in the wrist if it occurs continuously	Trials are carried out on automatic machines regularly.	3	7	3	63
R.2.1.	Causes back pain (back injury) due to the direction of the load being lifted and the frequency of transfer.	Trials are carried out on automatic machines regularly.	2	10	7	140
R.2.2.	Causes muscle and spinal injuries.	The existence of training or training for workers on correct and safe lifting techniques.	4	9	3	108
R.2.3.	Causes muscle cramps as well as numbness and pain.	Not yet implemented.	8	3	4	96
R.3.1.	Causes pain in the neck, back, arms and stomach especially if the bending modification will increase the pain in those parts.	Regular checking.	2	10	3	60

Table 5: Ergonomic Risk Management on Painting Activity

Risk Specification	Causes	Improvement Suggestion Design
Operators lack understanding of good and correct manual lifting techniques.	Damaged automatic machine. Lack of knowledge in correct and safe lifting techniques on products. Lack of material handling tools. Product weight.	a. **Suggestion 1**: Designing SOP that regulates manual product lifting technique.
Operators with forward bending position when lifting products from wire cart.	Uneven wire cart.	b. **Suggestion 2**: Work facility design such as wire cart that can facilitate operator's job. 
When the operator performs the coating process by moving the arm when placing the Disc Brake product, the distance is quite far from the space provided.	Inaccurate Workplace Layout.	c. **Suggestion 3**: Improvements to the Workplace layout design for the Coating process and adding the design of work facilities such as tables for placing Disc brake products after the coating process. 

Training Material Decision Making for Mechanics Using Analytic Hierarchy Process (AHP): A Case Study of PT United Tractors Tbk.

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ABSTRACT

United Tractors is committed to providing total solutions for products and services that customers need to provide the best satisfaction for customers in using products and services. In order for products and service quality to always meet customer specifications and expectations, we provide excellent service through the after-sales service quality assurance program, namely UT Guaranteed Product Support (UT GPS) [1]. In order to maximize On-Time in full Machine maintenance period, improving mechanical competence is one of the main things that must be done. To determine the right material of training, we need to make the right decisions using the Multi-Criteria Decision Making (MCDM) method by the Analytical Hierarchy Process (AHP) application. In this research, decision making is based on business criteria with parameters of population, the number of job orders and the number of parts orders and combined with job frequency criteria by job classification criteria with Preventive Maintenance (PM) parameters, Machine Trouble Shooting (MTS) and Component Overhaul (OVH). In this paper data matrix is inputted to the application super decision for getting the result. Rank of training based on business criteria is a result for get the decision making for start training based on priority number at PT United Tractor Tbk.

CCS CONCEPTS

• **Applied computing**; • **Operations research**; • **Decision analysis**; • **multi-criteria optimization and decision-making**;

KEYWORDS

Decision-making process, AHP, MCDM, weighting criteria, super decision application

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1 INTRODUCTION

The Construction Machinery business unit, which carries the name United Tractors, plays a role as the leading and largest distributor of heavy equipment in Indonesia. As the sole distributor of Komatsu, UD Trucks, Scania, Bomag, and Tadano products, United Tractors provides heavy equipment, trucks, cranes and buses for use in the mining, plantation, construction and forestry sectors as well as for material handling and transportation [1]. United Tractors is committed to providing total solutions for products and services that customers need to provide the best satisfaction for customers in using products and services. In order for products and service quality to always meet customer specifications and expectations, is provided by UT GPS excellent service through the after-sales service quality assurance program, namely UT Guaranteed Product Support (UT GPS) [1]. Three Main Customer Experience: Services that cover aspects of spare parts delivery, mechanics and machine maintenance period, which are offered through a service feature called On-Time-In-Full (OTIF) [1].To maximize On-Time in full Machine maintenance period, improving mechanical competence is one of the main things that must be done. To determine the right material of training, we need to make the right decisions using the Multi-Criteria Decision Making (MCDM) method using the Analytical Hierarchy Process (AHP) application. In this research, decision making is based on business criteria with parameters of population, the number of job orders, and a number of parts orders and combined with job frequency criteria by job classification criteria with Preventive Maintenance (PM) parameters, Machine Trouble Shooting (MTS) and Component Overhaul (OVH).

2 LITERATUR REVIEW

Decision analysis is a philosophy and a social technical process to create value for decision makers and stakeholders facing difficult decision involving multiple stakeholders, multiple (possibly conflicting) objectives, complex alternatives, important uncertainties, and significant consequences. Decision analysis is founded on an axiomatic decision theory and uses insights from the study of decision making [2]. Decision making is an intricate process in which organizations suffer to obtain the final desired outcome successfully. The decision-making process is the act of selecting the most suitable action to fulfill the desired goals and objectives. Because decision making is a daily task in our everyday routines, effective tools should be used to analyze all aspects of decision-making problems. Multi-Criteria Decision Making (MCDM) is a

Table 1: Define of step AHP [4]

Step	Dimension of Ranking
Goal	The vision/ mission to do and develop. Example : To buy a perfect car.
Alternative	The types of vision/mission Example : Honda, Toyota and Nissan
Criteria	The explanation of reason to choose that alternative. Example : Price, type, size and color

well-structured and multidimensional process developed to tackle decision-making problems in different fields and search for the most attractive alternative with consideration of all relevant criteria. Due to its powerful tools, it analyzes complex decision-making problems in different fields [3].

AHP is a traditional multi-criteria decision-making method combining qualitative and quantitative analysis [4]. Step of AHP as follows:

- Define the Problem
- Decision Structure (Goal, Criteria, and Alternative)
- Measure Weighting by Questionnaire Survey [5]and higher value is a priority or small value is priority [6]
- Data Random Consistency Index (RI)
- Calculate Consistency Index (CI)
- Calculate Consistency Ratio (CR) [7]
- Result rank of alternative

Criteria in AHP must been constructed as illustrated in the formulae below: [8]

2.1 Create a matrix of Criteria

$$A = \begin{bmatrix} a^{11} & a^{12} & a^{1n} \\ a^{21} & a^{22} & a^{2n} \\ a^{n1} & a^{n2} & a^{nn} \end{bmatrix} \tag{1}$$

$$[Aji]\,,\ where, i, j = 1, 2,\ \ldots,\ n,$$

$$Aij = 1\ for\ i = j,\ \text{and}\ Aij = \frac{1}{Aji}\ for\ i\ \neq j$$

The formula (1) deals with the matrix of dimension (n x n), where n = comparison number of factors. The elements value that are related to the diagonal of the matrix is equal to 1 such as Aij = 1. Based on AHP, it is possible for preference that is reciprocal and this is expressed by Aij=1/Aji for i ≠j. For example, if factor of ith is, x times more important than the j-th factors (e.g.: Aij = x), meanwhile the automatically assume that j-th factors is 1/ x as important between i-th element (aji= 1/x) and/or Aji= 1/aji.

The calculations of criteria weight and alternative local weight that are selected from existing matrices are calculated through the use normalization procedure. Equations of criteria weight and alternatives local weight are explained as can be seen in equation 2. The obtained alternatives global weight that are synthesize with the local weight

$$B\ x\ V = \begin{bmatrix} b^{11} & b^{12} & b^{1n} \\ b^{21} & b^{22} & b^{2n} \\ b^{n1} & b^{n2} & b^{nn} \end{bmatrix} \begin{bmatrix} v^1 \\ v^2 \\ v^n \end{bmatrix} \tag{2}$$

From formula (2), B explains alternatives of local weight (row) and the criteria of local weight (column). Also, V explained transpose of criteria local weight and the Global weight is derived by multiplying the matrices of B and V. For easier AHP weighting, all of alternatives and criteria that are created should be analyzed and evaluated using computer software. More also, consistency is an important aspect of AHP and must be checked. The AHP consistency test has been represented in the formulae below. However, the consistency of data can also be tested using Expert Choice Software [9].

Maximal Eigenvalue.

$$\lambda \max = \frac{1}{n} = \sum_{i=1}^{n} \frac{(Aw)\,i}{wi}$$

Consistency Index (CI)

$$CI = \frac{(\lambda \max - n)}{n - 1}$$

Consistency Ratio (CR)

$$CR = \frac{CI}{RI}$$

Value (CR) ≤ 0.1 , consistent data

Value (CR) > 0.1 , data inconsistent and revise process

3 METHODOLOGY

4 ANALYTIC HIERARCHY PROCESS

In Figure 1. following step on analytic hierarchy process. First step define problem in company process. The second step is making decision structure. Structure in analytic hierarchy process divided by goal, criteria and alternative. Third step is a define goal. Decision of the goal in this research is a priority of training for product support mechanic competencies. Forth step defining criteria and alternative. Criteria conduct the value to choose the alternative [10].

The next step is measuring the matrix for getting the consistency ratio. Data can be use if have consistency ratio < 0.1 and data must be review if measuring data consistency ratio > 0.1 [9].

Analytic hierarchy process with consistent ratio below 0.1 its mean data analytic is consistent and AHP analysis can getting data rank of alternative and getting priority of training [11].

In Figure 2, Analytic Hierarchy Process step goal defining by rank of material training. Step criteria divided by two as criteria of business and criteria of job. Criteria of business consist of population unit, job order and parts order. Criteria of job consist of

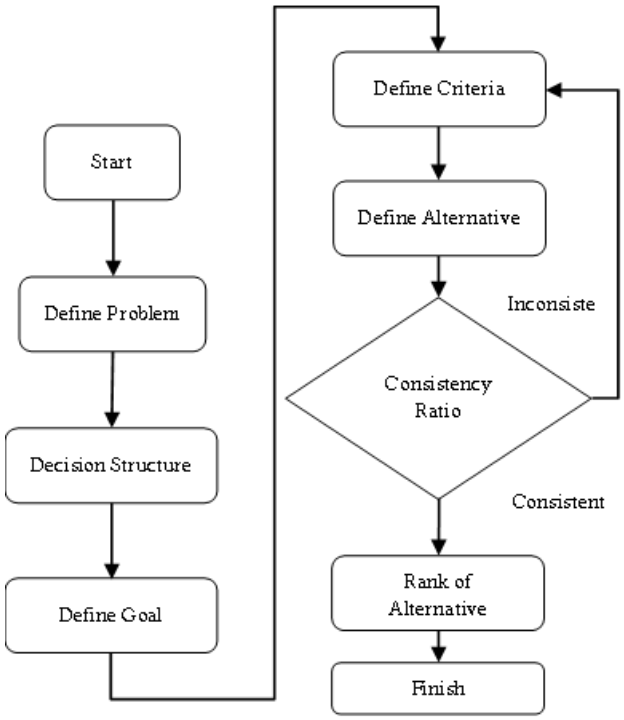


Figure 1: Flow Process of research [4]

preventive maintenance, machine trouble shooting and component overhaul. [12]

Step Alternative defining by rank of unit. Kind of unit involve consist of Scania unit, Komatsu unit, Bomag unit, UD Truck unit and Tadano unit.

Consistency Index (CI): 0.012

Consistency Ratio (CR): 0.0104

In Table 2 matrix data by population unit defining by comparation population unit criteria node in alternative kind of unit cluster. Komatsu is strongly to very strongly more important than Bomag. Scania is equally to moderately more important than Bomag. Bomag is equally as important as Tadano. Bomag is equally as important as UD Truck. Komatsu is strongly more important than Scania. Komatsu is very strongly more important than Tadano. Komatsu is strongly to very strongly more important than UD Truck. Scania is equally to moderately more important than Tadano. Scania is equally as important as UD Truck. Tadano is equally as important as UD Truck. Result in matrix Table 2 is consistent data.

Consistency Index (CI): 0.001

Consistency Ratio (CR): 0.0009

In Table 3 matrix data by job order defining by comparation job order criteria node in alternative kind of unit cluster. Komatsu is strongly to very strongly more important than Bomag. Scania is equally to moderately more important than Bomag. Bomag is equally as important as Tadano. Bomag is equally as important as UD Truck. Komatsu is moderately to strongly more important than Scania. Komatsu is very strongly more important than Tadano. Komatsu is strongly to very strongly more important than UD Truck. Scania is equally to moderately more important than Tadano. Scania is equally to moderately more important than UD Truck. Tadano is equally as important as UD Truck. Result in matrix Table 3 is consistent data.

Consistency Index (CI): 0.015

Consistency Ratio (CR): 0.0133

In Table 4 matrix data by parts order defining by comparation parts order criteria node in alternative kind of unit cluster. Komatsu is very strongly more important than Bomag. Scania is equally to moderately more important than Bomag. Bomag is equally as important as Tadano. Bomag is equally as important as UD Truck. Komatsu is strongly to very strongly more important than Scania. Komatsu is very strongly more important than Tadano. Komatsu is very strongly more important than UD Truck. Scania is equally to moderately more important than Tadano. Scania is equally as important as UD Truck. Tadano is equally as important as UD Truck. Result in matrix Table 4 is consistent data.

Consistency Index (CI): 0.015

Consistency Ratio (CR): 0.0133

In Table 5 matrix data by preventive maintenance defining by comparation preventive maintenance criteria node in alternative kind of unit cluster. Komatsu is very strongly more important than Bomag. Scania is equally to moderately more important than Bomag. Bomag is equally as important as Tadano. Bomag is equally as important as UD Truck. Komatsu is strongly to very strongly more important than Scania. Komatsu is very strongly more important than Tadano. Komatsu is very strongly more important than UD Truck. Scania is equally to moderately more important than Tadano. Scania is equally to moderately more important than UD Truck. Tadano is equally as important as UD Truck. Result in matrix Table 5 is consistent data.

Consistency Index (CI): 0.014

Consistency Ratio (CR): 0.0123

In Table 6 matrix data by machine trouble shooting defining by comparation machine trouble shooting criteria node in alternative kind of unit cluster. Komatsu is moderately more important than

Table 2: matrix data by population unit

Comparation	Komatsu	Scania	Tadano	Bomag	UD Truck
Komatsu	1	0.2	0.14	0.16	0.16
Scania	5	1	0.5	0.5	1
Tadano	7	2	1	1	1
Bomag	6	2	1	1	1
UD Truck	6	1	1	1	1

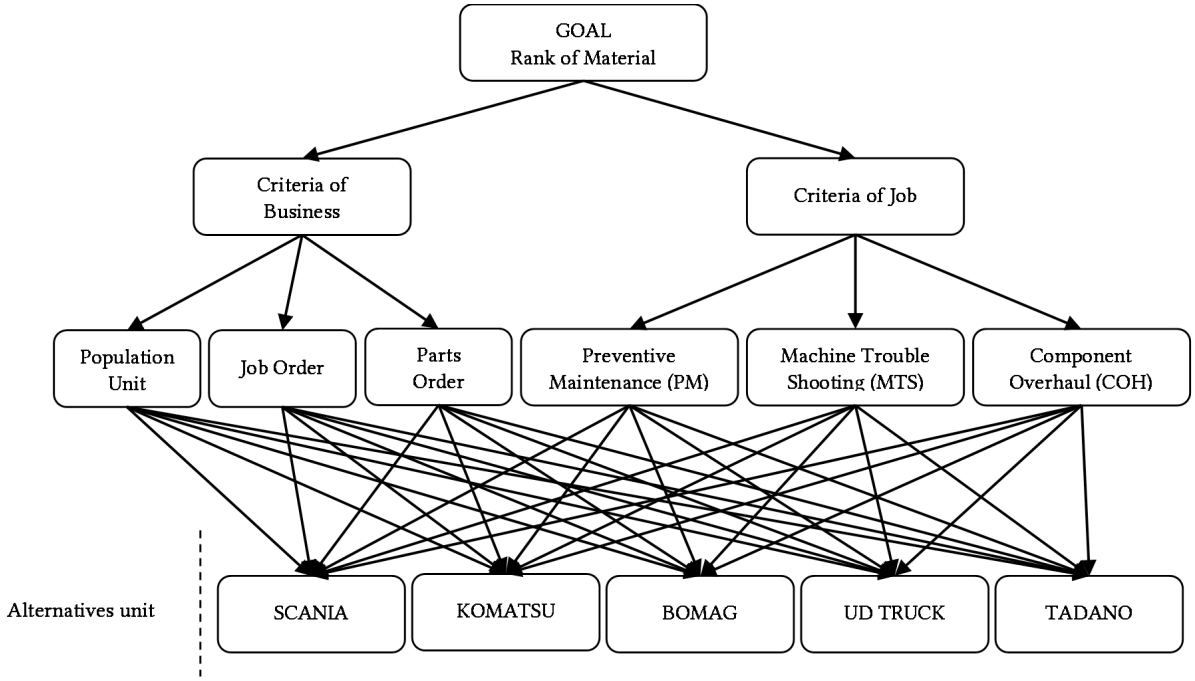


Figure 2: Decision Structure Analytic Hierarchy Process

Table 3: Matrix Data by Job Order

Comparation	Komatsu	Scania	Tadano	Bomag	UD Truck
Komatsu	1	0.25	0.14	0.16	0.14
Scania	4	1	0.5	0.5	0.5
Tadano	7	2	1	1	1
Bomag	6	2	1	1	1
UD Truck	7	2	1	1	1

Table 4: matrix data by parts order

Comparation	Komatsu	Scania	Tadano	Bomag	UD Truck
Komatsu	1	0.16	0.14	0.14	0.14
Scania	6	1	0.5	0.5	0.5
Tadano	7	2	1	1	1
Bomag	7	2	1	1	1
UD Truck	7	2	1	1	1

Table 5: matrix data by preventive maintenance (PM)

Comparation	Komatsu	Scania	Tadano	Bomag	UD Truck
Komatsu	1	0.16	0.14	0.14	0.14
Scania	6	1	0.5	0.5	0.5
Tadano	7	2	1	1	1
Bomag	7	2	1	1	1
UD Truck	7	2	1	1	1

Table 6: Matrix Data by Machine Trouble Shooting (MTS)

Comparation	Komatsu	Scania	Tadano	Bomag	UD Truck
Komatsu	1	4	0.33	0.33	0.33
Scania	0.25	1	0.14	0.14	0.14
Tadano	3	7	1	1	1
Bomag	3	7	1	1	1
UD Truck	3	7	1	1	1

Table 7: Matrix Data by Component Overhaul (OVH)

Comparation	Komatsu	Scania	Tadano	Bomag	UD Truck
Komatsu	1	0.2	0.14	0.14	0.14
Scania	5	1	0.33	0.33	0.33
Tadano	7	3	1	1	1
Bomag	7	3	1	1	1
UD Truck	7	3	1	1	1

Bomag. Scania is very strongly more important than Bomag. Bomag is equally as important as Tadano. Bomag is equally as important as UD Truck. Scania is moderately to strongly more important than Komatsu. Komatsu is moderately more important than Tadano. Komatsu is moderately more important than UD Truck. Scania is very strongly more important than Tadano. Scania is very strongly more important than UD Truck. Tadano is equally as important as UD Truck. Result in matrix Table 6 is consistent data.

Consistency Index (CI): 0.014

Consistency Ratio (CR): 0.0123

In Table 7 matrix data by component overhaul defining by comparation component overhaul criteria node in alternative kind of unit cluster. Komatsu is very strongly more important than Bomag. Scania is moderately more important than Bomag. Bomag is equally as important as Tadano. Bomag is equally as important as UD Truck. Komatsu is strongly more important than Scania. Komatsu is very strongly more important than Tadano. Komatsu is very strongly more important than UD Truck. Scania is moderately more important than Tadano. Scania is moderately more important than UD Truck. Tadano is equally as important as UD Truck. Result in matrix Table 7 is consistent data.

5 RESULT AND DISCUSSION

5.1 Superdecison Application

In Figure 3 build analytic hierarchy process from data matrix continue input to application super decision. Application will calculate data comparation criteria and alternative. Result and analysis will be show in Figure 4

In Figure 4 showing Result from the application super decision with all data from criteria and alternative. Value of normalize by cluster getting rating as value 0.08 for Bomag, 0.57 for Komatsu, 0.17 for Scania, 0.08 for Tadano, 0.08 for UD Truck, 0.31 for job order, 0.12 for parts order, 0.55 for population unit, 0.13 for component overhaul, 0.73 for preventive maintenance, 0.12 for machine trouble shooting. From the data can be make result following Figure 5.

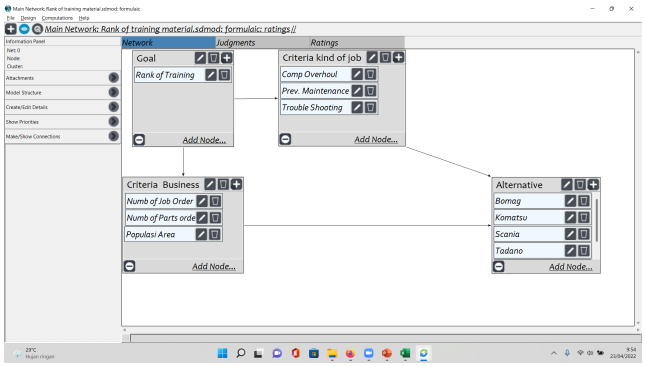


Figure 3: Superdecision Application

In Figure 5 elaborate rank of criteria. Criteria from data can getting result of rank as value 0.15 for job order, 0.06 for parts order, 0.27 for population area, 0.06 for component overhaul, 0.36 for preventive maintenance and 0.06 for trouble shooting. That mean weighting of criteria from the highest is preventive maintenance 36%, area population 27% Job order 15%, component overhaul 6,8%, trouble shooting 4,6% and smallest is parts order 6%.

In Figure 6 getting result rank of alternative as value 0.14 for Bomag, 0.57 for Komatsu, 0.17 for Scania, 0.08 for Tadano and 0.08 for UD Truck. That mean weighting of alternative from the highest is Komatsu 57%, Scania 17% UD Truck 8.4%, Bomag 8.1%, and Tadano 8.0% . data weighting of alternative can be getting result of rank of unit priority as Figure 7.

In Figure 7 result of rank model unit for prioritization training material for mechanic. Company can get decision of priority training start by rank of priority from the highest as Komatsu, Scania, Bomag, Tadano and UD Truck products. Combining data rank of unit and rank of job order material training getting result of the rank prioritization training material for mechanics include detailed job in Table 8.

Table 8: Rank Prioritization Training Material for Mechanics

Rank of Training	Model Unit	Material Training
Rank 1	Komatsu	Preventive Maintenance
Rank 2	Komatsu	Component Overhaul
Rank 3	Komatsu	Trouble Shooting
Rank 4	Scania	Preventive Maintenance
Rank 5	Scania	Component Overhaul
Rank 6	Scania	Trouble Shooting
Rank 7	UD Truck	Preventive Maintenance
Rank 8	UD Truck	Component Overhaul
Rank 9	UD Truck	Trouble Shooting
Rank 10	Bomag	Preventive Maintenance
Rank 11	Bomag	Component Overhaul
Rank 12	Bomag	Trouble Shooting
Rank 13	Tadano	Preventive Maintenance
Rank 14	Tadano	Component Overhaul
Rank 15	Tadano	Trouble Shooting

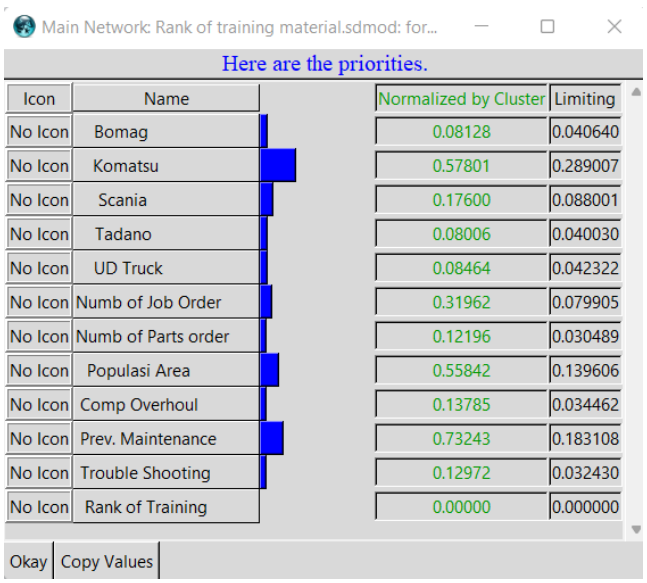


Figure 4: Visualization of Priority All Criteria and Alternative

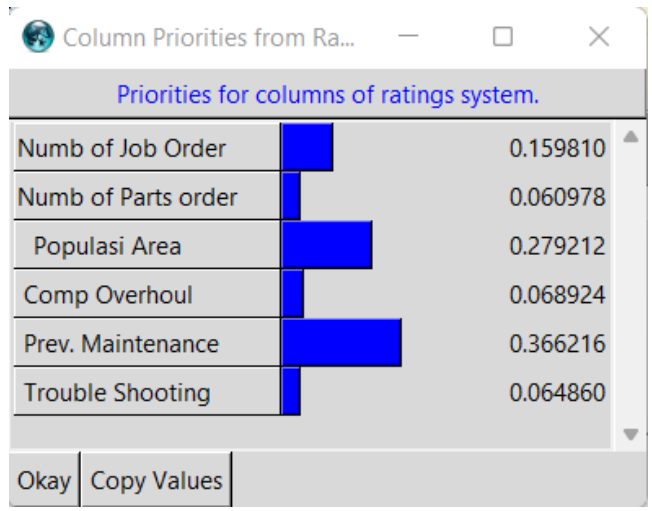


Figure 5: Visualization Important Rank of Criteria

Result of analytic hierarchy process with multi criteria in Table 8 define the decision-making rank priority of training material for mechanic. The data can be continuing with the scheduling and implementing at company.

6 CONCLUSION

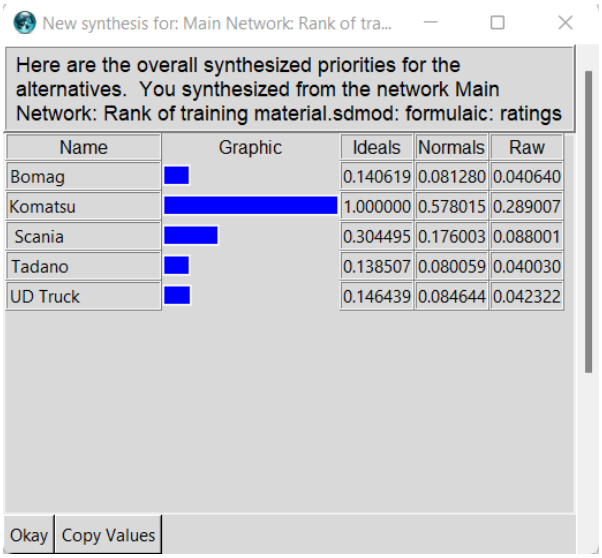
Decision-making with multi-criteria decision-making (MCDM) using the Analytic Hierarchy Process (AHP) makes the decision-making process of training materials to be carried out easier because the Super Decision application makes a summary of the priority of training materials that must be delivered to mechanics. result rank of alternative as value 0.14 for Bomag, 0.57 for Komatsu, 0.17 for Scania, 0.08 for Tadano and 0.08 for UD Truck. That mean weighting of alternative from the highest is Komatsu 57%, Scania 17% UD Truck 8.4%, Bomag 8.1%, and Tadano 8.0%. To increase the benefits of making training decisions on business conditions, further research should add criteria for training locations and the classification of mechanics who will conduct training.

ACKNOWLEDGMENTS

In this research only focus to make decision priority of training material unit Komatsu, Scania, Bomag, Tadano and UD Truck product in case study at PT United Tractors Tbk site Kutai Barat.

REFERENCES

[1] [1] PT United Tractors, "PT United Tractors Tbk Annual Report 2021," Jakarta, 2021. Accessed: Jul. 13, 2022. [Online]. Available: www.unitedtractors.com



Name	Graphic	Ideals	Normals	Raw
Bomag		0.140619	0.081280	0.040640
Komatsu		1.000000	0.578015	0.289007
Scania		0.304495	0.176003	0.088001
Tadano		0.138507	0.080059	0.040030
UD Truck		0.146439	0.084644	0.042322

Figure 6: Rank of Alternative

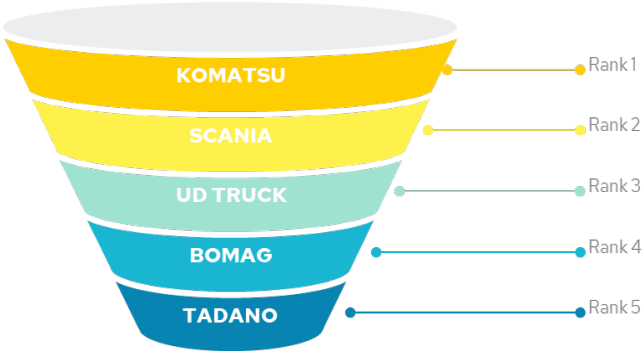


Figure 7: Rank Model Unit for Prioritization Training

[2] [2] X. Cui *et al.*, "Two-dimensional evaluation model of electrical equipment based on combined weighting and rating algorithm," *Energy Reports*, vol. 7, pp. 443–448, Apr. 2021, doi: 10.1016/j.egyr.2021.01.048.

[3] [3] A. Afandi, "PENERAPAN AHP (ANALYTICAL HIERARCHY PROCESS) TERHADAP PEMILIHAN SUPPLIER DI UD. NAGAWANGI ALAM SEJAHTERA MALANG."

[4] [4] C. Liu, S. Yang, Y. Cui, and Y. Yang, "An improved risk assessment method based on a comprehensive weighting algorithm in railway signaling safety analysis," *Safety Science*, vol. 128, Aug. 2020, doi: 10.1016/j.ssci.2020.104768.

[5] [5] P. Liu, B. Zhu, and P. Wang, "A weighting model based on best–worst method and its application for environmental performance evaluation," *Applied Soft Computing*, vol. 103, May 2021, doi: 10.1016/j.asoc.2021.107168.

[6] [6] V. L. Sivakumar, R. Radha Krishnappa, and M. Nallanathel, "Drought vulnerability assessment and mapping using Multi-Criteria decision making (MCDM) and application of Analytic Hierarchy process (AHP) for Namakkal District, Tamilnadu, India," in *Materials Today: Proceedings*, 2020, vol. 43, pp. 1592–1599. doi: 10.1016/j.matpr.2020.09.657.

[7] [7] A. Nikkhah, S. Firouzi, M. el Haj Assad, and S. Ghnimi, "Application of analytic hierarchy process to develop a weighting scheme for life cycle assessment of agricultural production," *Science of the Total Environment*, vol. 665, pp. 538–545, May 2019, doi: 10.1016/j.scitotenv.2019.02.170.

[8] [8] N. Filianie Aziz, S. Sorooshian, and F. Mahmud, "MCDM-AHP METHOD IN DECISION MAKINGS," vol. 11, no. 11, 2016, [Online]. Available: www.arpnjournals.com

[9] [9] F. Fernández-Tirado, C. Parra-López, and M. Romero-Gámez, "A multi-criteria sustainability assessment for biodiesel alternatives in Spain: Life cycle assessment normalization and weighting," *Renewable Energy*, vol. 164, pp. 1195–1203, Feb. 2021, doi: 10.1016/j.renene.2020.10.145.

[10] [10] N. Ranti Muntiari, dan Abdul Fadlil, A. Dahlan, and J. Soepomo, "Penentuan Kriteria Penginapan Menggunakan Metode Analytic Hierarchy Process."

[11] [11] C. Z. Raulescu, M. Radulescu, A. Alexandru, M. Ianculescu, and V. Vevera, "A multi-criteria weighting approach for Quality of Life evaluation," in *Procedia Computer Science*, 2019, vol. 162, pp. 532–538. doi: 10.1016/j.procs.2019.12.020.

[12] [12] S. N. Kamaruzzaman, E. C. W. Lou, P. F. Wong, R. Wood, and A. I. Che-Ani, "Developing weighting system for refurbishment building assessment scheme in Malaysia through analytic hierarchy process (AHP) approach," *Energy Policy*, vol. 112, pp. 280–290, Jan. 2018, doi: 10.1016/j.enpol.2017.10.023.

Analytic Hierarchy Process (AHP) Method for Choosing The Best Secondhand Injection Machine for PT PLA

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ABSTRACT

PT Parama Lentum Artindo or goes by the brand "Artiplast" is a humble startup in the plastic injection business. In the second year of its journey, Artiplast needed to buy a secondhand machine with 300 tons capacity to fulfill the demand from customers. After reviewing various secondhand injection machine options in the market available to date, the alternatives are narrowed down to three machine options, which are NISSEI FE360, POTENZA PT350, and CHENHSONG JM328. Analytic Hierarchy Process (AHP) method is used for choosing the best from the three alternatives. AHP is a multicriteria decision-making technique that can help in producing the best alternatives that comply with all criteria and are weighed based on each criteria's priority. The method will be implemented using Super Decisions. For this research, there are 4 criteria with 9 sub-criteria to be assessed. Based on the data processing, it is decided that POTENZA PT350 is the best option for Artiplast, with the highest weight value of 0.441, followed by NISSEI FE360 with 0.338, and lastly CHENHSONG JM328 with 0.221.

CCS CONCEPTS

• **General and reference** → Cross-computing tools and techniques; Evaluation.

KEYWORDS

Decision making, Machine selection, Multicriteria, Pairwise comparison, AHP (Analytic Hierarchy Process), Super Decisions

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1 INTRODUCTION

PT Parama Lentum Artindo or goes by the brand "Artiplast" is a humble startup in the plastic injection business. The journey begins when one of the founders got into retirement around 2020. He has been an expert in the plastic industry for more than 30 years and he was the first certified RJG®Master Molder in Southeast Asia in 2015. He also developed a new, unique, but effective method for plastic processing called SAPP (Scientific Approach Plastic Processing).

Artiplast begins with a single injection machine, which is a secondhand Toshiba IS130G with 130 tons capacity. Since then, they have been adding more secondhand machines to complete their fleet. The next machine they acquired was Arburg Allrounder 22S with 22 tons capacity, and a customized China-made 7 tons machine, making their low range machines complete already. Having low-range machines is a big advantage since it allows them to produce small-sized products with high precision.

However, as their biggest machine is the 130 tons one, they can only inject product possible with a total surface area projected to the clamping platen of about 400 cm^2 or 20 cm x 20 cm, regardless of its thickness. Also, the other limitation is the shot size or how much material can be injected which is directly connected to the product weight. The heaviest product to be injected cannot exceed 200 ccs or about 200 gr of material using the existing machine.

2 PROBLEM

In the second year of its journey, Artiplast got an order request to inject helmet shells. The helmet shell weighs 600 grams and the surface area projected to the platen is about 700 cm^2. The theoretical required clamping capacity to produce this product is 210 tons. However, due to the unique shape of the helmet, the molding will be much bigger than the products, making the minimum tonnage requirement increase to 300 tons.

When compared to the market price, the machine hourly rate for an injection machine is around IDR 1,000 /tons. Therefore, 300-tons-machines will generate IDR 300,000 /hour. This rate is then deducted with the human resource rate of IDR 50,000 /hour, the electricity consumption of IDR 75,000 /hour, and other costs (building, utilities, overhead, non-essential personnel) of IDR 125,000 /hour. After the deduction, the estimated income that this new machine can generate is around IDR 50,000 /hour. If we assume the machine will be running 24 hours a day, 30 days a month, with 80% efficiency, then it is expected to generate an income of around IDR 350 million /year. A brand-new machine might cost around IDR 1.5 billion, making it feasible to achieve a breakeven point in 5 years.

Unfortunately, the order of the helmet shell previously mentioned above, will not cover the full production capacity. The demand is only 2,500 pieces /month, which only takes around 55 hours of production (cycle time is 75 seconds). Hence, the new expected income is reduced to only around IDR 35 million /year.

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NISSEI FE360
Capacity : 360 tons
Origin : Japan
MFD : 1994
Controls : Porcheson
Price : IDR 295 mil.

Figure 1: : Machine option 1

POTENZA PT350
Capacity : 350 tons
Origin : China
MFD : 2007
Control : Porcheson
Price : IDR 262 mil.

Figure 2: : Machine option 2

CHENHSONG JM328
Capacity : 328 tons
Origin : China
MFD : 2011
Control : Native
Price : IDR 290 mil.

Figure 3: : Machine option 3

Concerning these numbers, the only feasible option for Artiplast was only buying a secondhand machine, which will cost around IDR 300-400 million, thus might achieve a breakeven point in 10 years.

After reviewing various secondhand injection machine options in the market available to date, the alternatives are narrowed down to three machine options, which are:

It is narrowed down into these three machines because the three of them has the most advantages and has passed all the requirements. All of them also has their own unique traits, when one excels in one aspect, and the other excels in another aspect. Since there are so many aspects and criteria to be weighed, it is very hard for Artiplast to decide the best one from raw data. We must develop some solution to reach the best decision while evaluating every aspect, where all aspects have their own importance level. To help with this problem, a decision support system in particular an analytic hierarchy process needs to be implemented for determining the best decision considering many important aspects and criteria.

3 LITERATURE REVIEW

3.1 Decision Support System

A Decision Support System (DSS) is an approach (or methodology) to support decision-making. DSS uses a flexible, interactive, and adaptable Computer Base Information System (CBIS), which was developed to support solutions to unstructured specific management problems [1]. There are several characteristics of the DSS, namely [2]:

a. DSS offers flexibility, adaptability, and fast response.
b. Allows the user to initiate and control input and output.
c. Can be operated with little or no professional programming assistance.
d. Provides support for decisions and problems whose solutions cannot be determined upfront.
e. Uses advanced data analysis and modeling tools.

Meanwhile, the objectives of the DSS can be described as follows [2]:

a. Help solve semi-structured problems.
b. Support managers in making decisions.
c. Increasing effectiveness is not decision-making efficiency.

So, it can be said that DSS can provide benefits for decision-makers in increasing the effectiveness and efficiency of work, especially in the decision-making process.

3.2 Analytic Hierarchy Process

AHP is a multicriteria selection-making method which could assist specific the overall selection operation with the aid of using decomposing a complex trouble right into a multilevel hierarchical shape of objectives, standards, and options [3]. AHP plays pairwise comparisons to derive the relative significance of the variable in every stage of the hierarchy and/or appraises the options withinside the lowest stage of the hierarchy to make the exceptional selection amongst options. AHP is an powerful selection-making approach specially while subjectivity exists and it's miles very appropriate to clear up troubles in which the selection standards may be prepared hierarchically into sub-standards [4]. The AHP approach is primarily based totally on 3 principles: first, the shape of the model; second, the comparative judgment of the standards and/or options; and third, the synthesis of the priorities.

The steps withinside the AHP approach regions may be visible in Figure 4. First, we outline the trouble or the aim that we're going to use AHP for. Second, we broaden the hierarchical framework with the aid of using decomposing the trouble right into a rational gadget like a network. Next, we assemble the pairwise evaluation matrix, what are the standards and sub-standards to be blanketed in a hierarchy mapping as may be visible in Figure 5.

And then we will carry out judgment for the ones pairwise comparisons through evaluating pairs of choice factors primarily based totally on their importance. Do now no longer neglect about to test the consistency of the result. Then repeat the method for all degrees withinside the hierarchy after which we will begin growing an ordinary precedence ranking. After synthesizing all the calculations, the great opportunity may be determined.

3.3 Pairwise Comparison Matrix

The pairwise comparison matrix is needed to calculate the impact on the alternatives being compared with the 1-9 measurement ratio scale (Table 1) developed by Saaty [6]. The comparison value is used for inverse comparison, namely $a_{ij} = 1/a_{ji}$ where a_{ij} or (a_{ji})

Table 1: : Saaty's 1-9 scale for AHP [5]

Intensity of importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

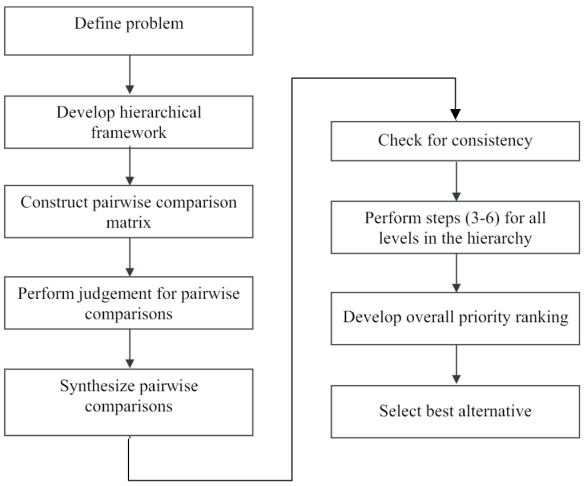

Figure 4: : AHP method steps

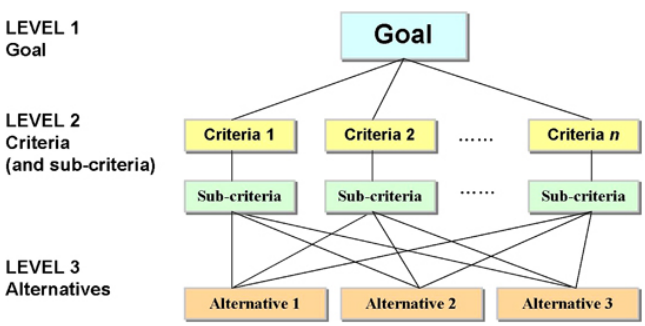

Figure 5: : AHP hierarchy mapping

indicates the level of importance of the i-th or j-th element. The pairwise comparisons in AHP are performed within the framework of a matrix and local priority vectors can be derived from estimates of the relative importance of the elements (clusters) being compared by solving the equation, as in this formula:

$$A \times w = \lambda_{max} \times w$$

Where A is the pairwise comparison matrix, w is the eigenvector, and $\lambda_{\max}$ is the largest eigenvalue of A. Saaty proposes several algorithms to approximate the value of w.

3.4 Inconsistency Ratio

The principle of AHP does now no longer call for ideal consistency. AHP permits inconsistency however affords a degree of the inconsistency in every set of judgments. This degree is an essential spinoff of the technique of deriving priorities primarily based totally on pairwise comparisons. It is herbal for humans to need to be constant. Being constant is frequently notion of as a prerequisite to clean thinking. However, the actual international is rarely flawlessly constant, and we are able to research new matters best through making an allowance for a few inconsistency with what we already know.

A degree of inconsistency is computed for every set of judgments while making paired comparisons. Inconsistency follows the transitive property; for example, in case you had been to mention that A > B, and B > C, then say that C > A, you'll were inconsistent. However, as defined below, the AHP and Expert Choice®"inconsistency ratio" measures greater than simply transitive consistency.

The priorities derived from relative pairwise comparisons are computed because the normalized values of the proper hand eigenvector related to the most important eigenvalue of the reciprocal matrix shaped from the pairwise comparisons.

The biggest eigenvalue (there are more than one answers or values simply as there are for the quadratic formula) is called $\lambda_{\max}$. The nearer $\lambda_{\max}$ is to n, the variety of factors being compared, the greater constant are the judgments. If judgments are flawlessly constant, $\lambda_{\max}$ will identical n. Thus, the distinction among $\lambda_{\max}$ and n, may be used as a degree of inconsistency. Instead of the usage of this distinction directly, Saaty [6] described a consistency index (CI) as:

$$CI = \frac{(\lambda_{max} - n)}{(n - 1)}$$

And to calculate the consistency ratio (CR), then:

$$CR = \frac{CI}{RI}$$

Where RI is Random Index, the consistency index of a randomly generated pairwise evaluation matrix. RI relies upon at the quantity of factors being compared (i.e., length of pairwise evaluation matrix), and takes on following values:

Table 2: : Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

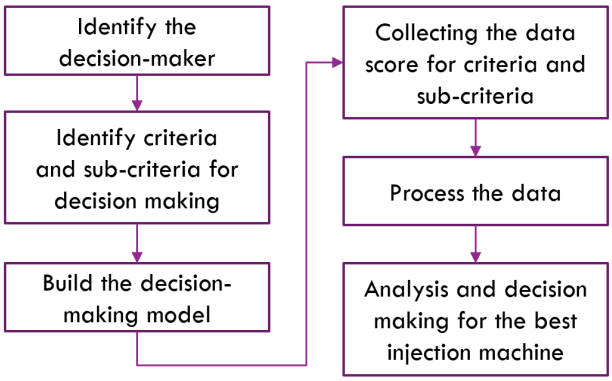

Figure 6: : Steps for research methodology

4 RESEARCH METHODOLOGY

To find out the best secondhand injection machine for Artiplast, we need concrete steps as the research methodology, as can be seen in Figure 6.

4.1 Identifying The Decision Maker

We must start by first identifying who the decision-maker will be. The decision-maker, or we can consider them the evaluator or assessor, should be someone who completely understands the technical and business aspect of buying a secondhand machine and have the expertise for comparing and assessing the actual machines. This person also must be of top-level who holds the power to make a decision and can prioritize the more important criteria from the less important criteria. In this research, the decision-maker consists of three respondents. The director himself, as this is a big investment, the technical advisor, and the technical assistant.

4.2 Identify Criteria and Sub-Criteria for Decision Making

After identifying the decision-maker, we have to determine what are the criteria that can determine which one among the three options is the best secondhand machine. The most important thing to consider when buying a secondhand machine is the condition of the machine itself. Any good brand or younger manufacturing age will have no effect if the previous operator or owner or user used the machine wrongly and did not do the necessary maintenance. Therefore, the condition of the machine has to be evaluated upon an on-site trial run. The criteria condition will be divided into two sub-criteria, namely Mechanical and Electrical, since the two of them may have different condition stages.

The second criterion is the specification of the machine. It was mentioned before that the minimum clamping tonnage necessary is 300 tons, any more than that is a bonus and an opportunity for larger prospects in the future. Also, the brand and manufacturing date of the machine will affect the robustness and reliability of the machine in the upcoming years.

The third criterion is the price. Since the budget of Artiplast is limited, the price will be a deciding factor. The price will be divided into two, the machine itself, and the cost to transport the machine to the Artiplast facility. The transportation cost will also represent the location and the dimension of the machine.

The fourth and last criterion is the owner. Buying secondhand machines can be very subjective when it comes to dealing. There are many things the assessors may have missed when doing the on-site evaluation. Therefore, the honesty of the owner is important. Other than that, the communication skill of the owner will also ease the acquisition process of the machine.

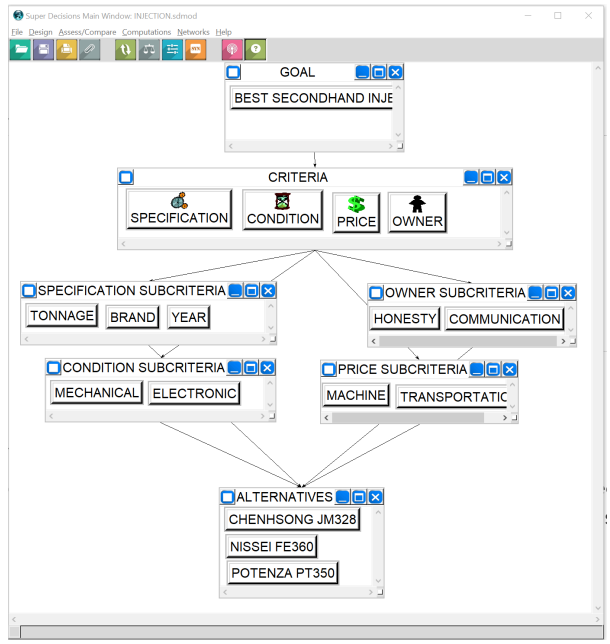

Figure 7: : Decision-making model

4.3 Build The Decision-Making Model

After considering all the criteria and sub-criteria above, a decision-making model of the hierarchical chart can be drawn. The visualization can be seen in the Figure 7.

GOAL - CRITERIA COMPARISON					
	CONDITION	OWNER	PRICE	SPEC.	EIGEN
CONDITION	1.00	4.00	2.00	3.00	0.469
OWNER	0.25	1.00	0.33	0.33	0.084
PRICE	0.50	3.00	1.00	0.50	0.194
SPEC.	0.33	3.00	2.00	1.00	0.252
Inconsistency Index : 0.05977					

Figure 8: : Goal – Criteria comparison result

MECHANICAL - MACHINE COMPARISON				
	I	II	III	EIGEN
I	1.00	0.20	3.00	0.109
II	5	1.00	0.5	0.581
III	0.33	2.00	1.00	0.309
Inconsistency Index : 0.00355				

Figure 9: : Mechanical – Machine comparison result

NAME	PRIORITIES
CHENHSONG JM328	0.22116
NISSEI FE360	0.33773
POTENZA PT350	0.44111
BEST SECONDHAND INJECTION MACHINE	0
CONDITION	0.26220
SPECIFICATION	0.56501
PRICE	0.11750
OWNER	0.05528
MECHANICAL	0.19665
ELECTRONIC	0.06555
TONNAGE	0.36631
BRAND	0.06894
YEAR	0.12975
MACHINE	0.09792
TRANSPORTATION	0.01958
HONESTY	0.04607
COMMUNICATION	0.00921

Figure 10: : Final sub-criteria weight priorities result

4.4 Collecting The Data Score for Criteria and Sub-Criteria

The assessment will be done by direct on-site evaluation. Some of the assessments will be quantitative and some will be qualitative. The quantitative datasets will be directly converted into the comparison scale. The qualitative assessment will be done using questionnaires for each evaluator to compare based on subjectivity. When there is inconsistency in the result, the respective criteria will be open for discussion until an agreement is achieved.

After collecting the data for the criteria and sub-criteria, the evaluators have to decide and compare the importance of each criterion and sub-criteria, and their significance to the goal.

4.5 Processing The Data

The data will then be processed using an Analytical Hierarchy Process based decision-making software: Super Decisions.

4.6 Analysis and Decision Making for The Best Injection Machine

The result from the Super Decisions program will directly pinpoint the best alternative to achieve the goal based on the criteria and sub-criteria.

5 ANALYSIS AND FINDINGS

The decision-making model in Figure 7 will be the basis for choosing the best secondhand injection machine for Artiplast. To make this decision, it is necessary to collect data regarding the level of importance of each criterion and sub-criteria based on the relationship that occurs between these criteria and sub-criteria. The results of the assessment in Table 2 are examples of assessing the importance of each criterion in relation to the goal to be achieved. The results of this assessment are shown in the form of a pairwise comparison matrix.

Based on [7], the value index rule that can be given starts from the number 1 which indicates that the two elements being compared are equally important until the number 9 which indicates that one element is more important than the other elements.

Based on the table shown in Figure 8, it can be seen that the comparison of criteria CONDITION (in the row) and criteria SPEC. (in the column) produces a value of 3 which indicates that the condition criteria are somewhat more important than the specification criteria in considering which machine to choose.

Another example of importance assessment based on the model in Figure 7 is the comparison between machine criteria and mechanical condition sub-criteria. This second example can be seen in Figure 9 where the Roman numerals I to III represent NISSEI, POTENZA, and CHENGHSONG, respectively. The interpretation of the assessment in Figure 9 is somewhat different from the assessment in Figure 8. For example, the comparison between row I, and column III shows the number 3. This shows that CHENGHSONG is somewhat superior to NISSEI in terms of mechanical condition. The two-way relationship between machine criteria and other criteria creates an inverse assessment where machine criteria are used as control criteria for the assessment of other criteria. After all the assessment processes are carried out, it is necessary to continue with testing the consistency of the assessment where the resulting inconsistency value should not be more than 0.1, otherwise, the assessment must be repeated. All assessment results in this research show the level of consistency that meets the requirements.

Based on the weight obtained, it is concluded that POTENZA PT350 is the best secondhand machine option for Artiplast. This is shown by the largest weight value owned by POTENZA compared to other machines. Based on the weights in Figure 8, it can be seen that Artiplast is very concerned about the machine condition in

SUBCRITERIA	MACHINE
MECHANICAL	POTENZA PT350
ELECTRONIC	CHENHSONG JM328
TONNAGE	NISSEI FE360
BRAND	NISSEI FE360
YEAR	POTENZA PT350
MACHINE	POTENZA PT350
TRANSPORTATION	POTENZA PT350
HONESTY	CHENHSONG JM328
COMMUNICATION	CHENHSONG JM328

Figure 11: : Goal – Criteria comparison result

choosing machines. The second most important thing to consider when choosing a machine is the specification of the machine. The order of importance of each of these sub-criteria can be obtained by sorting the weights in Figure 10 from the largest to the smallest. Thus, it is also known that the criteria with the lowest priority in selecting machines are the communication skill of the owner.

Also, based on the assessment process that has been carried out, the information about the advantages possessed by each machine in certain sub-criteria is obtained. The result in Figure 11 shows the information in question. Based on the table, it is known that NISSEI actually has the advantage in tonnage capacity, which is Artiplast's main priority in choosing machines. But in fact, the results of data processing show that POTENZA was chosen as the best machine option. This indeed makes sense, considering the advantages of POTENZA which are obtained from several sub-criteria that occupy high priority. Most of these sub-criteria can be met by POTENZA compared to other alternative suppliers.

Lastly, with the help of the Super Decisions program, we can find out the sensitivity analysis of each criterion (Figure 12). This sensitivity analysis is used to analyze how the priorities of the alternative solutions change as we vary the priority of one or more decision-making criteria. This means that the result of the assessment process can differ when each criteria weight or priority is changed by shifting the X-axis value (the current value is 0.5).

6 CONCLUSION

The AHP method can be used and very helpful in selecting the best secondhand injection machine for Artiplast based on the criteria of machine condition, machine specification, price, and owner factor.

These criteria are divided into 9 sub-criteria which are: mechanical condition, electrical condition, tonnage capacity specification, machine brand, machine manufacturing date, the price of the machine, the transporting cost for the machine, owner's honesty, and communication.

From this research, POTENZA PT350 is selected as the best option for buying a secondhand injection machine for Artiplast based on the weight result, which is 0.441, followed by NISSEI FE360 with 0.338, and lastly CHENHSONG JM328 with 0.221.

With this result followed by detailed and quantified "points" for each machine, the decision maker of PT Artiplast can rest assured

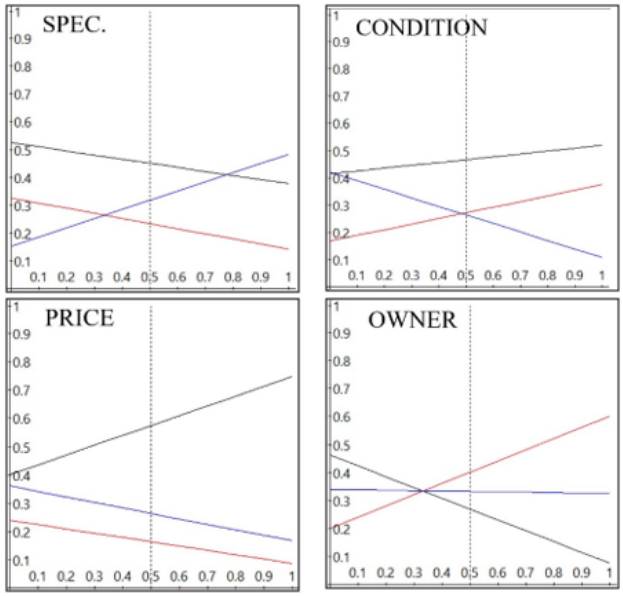

Figure 12: : Sensitivity analysis of each criterion

and have more confidence in buying the particular secondhand machine.

7 RECOMMENDATION

In the future, this AHP method with the same configuration and criteria importance value can be directly used in selecting secondhand machines for Artiplast in other cases or opportunities. We can also input the new machine options, redo the assessment for the pairwise comparisons, and then re-synthesize using Super Decisions for the result.

It is also very possible to make a software or an application which is easier to use for general user. For example, we can make mobile phone application with some preset criteria where the user can choose to activate or deactivate each criterion, to match their needs.

Other than that, Artiplast can also add more criteria or subcriteria when necessary and try to quantify some of the qualitative criteria.

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REFERENCES

[1] Turban, E, 2005, *Decision Support Systems and Intelligent Systems*, Edisi Bahasa Indonesia Jilid 1, Andi, Yogyakarta

[2] Laudon, K. C., Laudon, J. P., 1998, *Management Information Systems New Approaches to Organization & Technology*, 5th Edition, Prentice-Hall International. Inc.

[3] Sharma, B.C., Gandhi, O.P., 2008, *Safety assessment of lubricating oil using AHP and vector projection method*, Industrial Lubrication and Tribology, 60(5), pp.259-265.
[4] Tuzmen, S., Sipahi, S., 2011, *Amulti-criteria factor evaluation model for gas station site selection*, Proceeding of 2nd International Conference On Business And Economic Research (2nd ICBER 2011),601-610.
[5] Meade, L.M., Sarkis, J.J.I.J., 1999, *Analyzing organizational project alternatives for agile manufacturing processes: an analytical network approach,* International Journal of Production Research, 37(2), pp.241-261.
[6] Saaty, T., 1980, *The analytic hierarchy process (AHP) for decision making*. In Kobe, Japan (pp. 1-69).
[7] Saaty, T.L., 1991, *Some mathematical concepts of the analytic hierarchy process,* Behaviormetrika, 18(29), pp.1-9.

Analytical Hierarchy Process (AHP) for Selection of Project Management Software to Support Remote Working: A Case Study at Logistics Division of a National EPC Company in Indonesia

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ABSTRACT

Good project management is the main pillar of a project's success from an internal perspective. However, in 2020, the world was being hit by a sudden disruption in the form of the pandemic disease which greatly affects all aspects of social life. One of the effects of this pandemic is a large-scale social restriction, which is the limitation of a large group of people in one activity. This limitation will lead to the working from home system implementation for some companies. The implementation of this new working system will lead to the project performance and quality as well. The use of project management software can maintain or even increase the performance of the project. The objective of the thesis work is to be able to determine the criteria needed in a project management software and decide the suitable one in a logistics department. The analytical hierarchy process method was used in this research. Based on interviews and literature reviews, the criteria used are project schedule, collaboration, and task / Kanban. Microsoft Project is being on the first rank rather than other software that has a weight value on project schedule, collaboration, and task / Kanban criteria are 0.6887, 0.5870, and 0.4502.

CCS CONCEPTS

• **General and reference**; • **Document types**; • **General conference proceedings**;

KEYWORDS

Project, Management, Software, AHP, Working from Home, Microsoft Project, Asana, Trello

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1 INTRODUCTION

The case study that will be highlighted come from Project X that has been constructed since 2016. One of the EPC company work along with other three EPC companies won a contract with the client in terms of construction and marine works on a project. The commissioning of the project has been delayed for several times and for any reasons regarding to the shipment problems. This project continued to experience setback due to the disruption in 2020, namely the COVID-19 pandemic. This is due to many factors, one of which is the implementation of new regulations in the form of social distancing and large-scale restriction regulation. The project will also result in high overrun costs due to the emergence of additional costs.

The COVID-19 pandemic has created a new work system in several companies, which is being called as working from home. The main purpose of this new working system is to suppress the spread of the virus in the new cluster in the offices. However, this work system also has obstacles that must be faced by team members, one of which is the work that cannot be monitored properly. The schedule of activities and many tasks often can't be controlled and tracked while working at home due to the lack of documents in the form of hard copies, supervision from supervisors, and miss communication in a team. These obstacles can be overcome by using a project management software which has many features that can help some work while working at home so that later in the future, working by telework will increasingly being applied.

2 PROJECT MANAGEMENT

Projects are one of another than other works. A project can be described as an activity that must be used to create a unique product, service or result [1]. The duration can be vary from a few weeks to several years duration. Moreover, all activities that will determine the quality policies, objectives, and responsibilities so that the project will achieve the customer's satisfaction and needs will be defined as quality management processes [2].

Project management can be defined as an implementation of knowledge, skills, tools, and techniques on several activities such as initiating, planning, executing, monitoring and controlling, and closing in order to achieve project goals within budgeted cost, schedule, and performance criteria [1]. An effective project management

is how to plan, manage, and deliver projects on time and within budget ranges 20. Many factors influence the success of a management project.

2.1 Project Phase & EPCC

Basically activities on a project begin with initiation, planning, execution, monitoring and controlling, and closing [1]: project initiation, project planning, project execution, project performance & control, and project closure.

An EPC project is a project where the contractor works on a project with the scope of responsibility for completing the work including design studies, material procurement and construction as well as planning for the three activities 15. EPC projects are also referred to as projects that are quite complex, complicated and rich in problems [16]. The definition of EPC also refers to a management system that is able to manage various elements, which are related to each other in building an industry. These elements include engineering fields from various disciplines (process, civil, mechanical, electrical, instruments, materials, etc.), in finance (financing, budgeting, cost control, financial management, etc.), material and equipment procurement from within and outside the country, in shipping sector, in manpower sector and others [19]. The project phases of the EPC project will be explained as follows 5: engineering, procurement, construction, and commissioning.

3 TELEWORKING

At the end of December 2020, Wuhan Municipal Health Commission, China, reported a cluster of cases of pneumonia in Wuhan. A coronavirus was eventually identified. On February 11th, 2020, the World Health Organization announced an official name for the disease that is causing the 2019 novel coronavirus outbreak. The new name of this disease is coronavirus disease 2019, abbreviated as COVID-19. Through The Jakarta Post, Mr. Joko Widodo announced that on Monday, 2nd 2020, Indonesia confirmed that there was two first cases of COVID-19.

One of the biggest impacts of COVID-19 pandemic is large-scale social restriction or PSBB implementation at almost all provinces in Indonesia. These policies have been regulated in PP No. 21 of 2020 and Minister of Health Regulation No. 9 of 2020. Large-scale social restriction policy including school and workplace holiday, limitation of socio-cultural activities and restriction of large group on public activities. This restriction will lead to the implementation of working from home for some industries.

Term of remote working which was referred to as working from home in previous years. The term of remote working first appeared in the book The Human Use of Human Beings Cybernetics and Society by Norbert Wiener in 1950 which uses the term 'telework' (this term is more popular in Europe to this day) 13. Started in 1970 in response to efforts to reduce commuting and energy consumption, the 1980s remote working rose again as a work setting flexible, which allows a work-life balance to be created [9]. In the 1990s, more attention was paid much to the issues of workplace design, facility management, and managing needs work time and workspace to drive productivity and effectiveness [7]. The concept of remote working began to get the attention of many parties at the end of the century 20, accompanied the emergence of communication technology and personal computers. Telecommuting term of "telework" became more popular in the 80s when workers were given the opportunity to completing tasks from home rather than coming to the office in person [12]. At that time, the application of telecommuting jobs (working remotely) enforced one day a week [14].

4 PROJECT MANAGEMENT SOFTWARE

Project management software is an application for planning, organizing, staffing, monitoring, controlling, and leading a project [6]. The purpose of project management software mostly can be described as follows [10]:

- Scheduling
- Project related information
- Gain visibility and insight
- Communicate and elaborate
- Productivity
- Quality

There are so many management project's tools and software out there with various purposes, benefits and cons. There are several criteria or elements were selected and determined that must be present in each management project's tools and software that will be used [3]:

- Task scheduling
- Resource management
- Collaboration
- Time tracking
- Estimation
- Risk assessment
- Change management
- Project analysis / reporting
- Document management
- Communication tools
- Process development method
- Portfolio management
- Access control
- Quality management
- Web based
- Issue tracking

There is so many project management software out there that can be used for various purposes. Some of the project management software examples can be described as follows: Assembla, Microsoft Project, Liquidplanner, Wrike, Trello, and Asana; meanwhile there will be three project managements will be evaluated. Microsoft Project is a pioneer in project management software, so almost all industries must be very familiar with and use this software. Others, based on 17, Trello and Asana are already two of the web-based project management software that are often and widely used individually and in large numbers during pandemic.

5 PREVIOUS STUDIES

Other studies have been conducted by several author related to the project management software selection for varies criteria. A comparison table of project management can be seen in Table 1.

Table 1: Studies Comparison

	Research Goals	Advantages	Disadvantages	Affordability	Collaboration	Project Schedule	Communication Tools	Task/ Kanban
Cicibas et al, 2010 [3]	To assess the strengths and weaknesses of PM softaware	Helping project managers in choosing appropriate PM by providing a set of criteria	Too complex because using so many criteria that might not be so important for other company		V	V	V	V
Gharaibeh, 2014 [4]	To help select the most appropriate package	Implementing the ISO/ IEC evaluation that can be applicable to a variety of software products in different areas	The products that offer the most features is usually the most difficult to implement, learn and support	V		V		
Kutlu, 2014 [11]	To select the best PM software based on different companies' managers	The criteria are evaluated by various managers from different companies	Using only mostly used 3 PM in 2014 that might be outdated nowadays	V			V	
Proposed Research, 2022	To provide the suitable PM software in a construction project during WFH implementation	Specific to logistics department only	Might be not suitable to other department and different project type	V	V	V	V	V

6 RESEARCH METHODOLOGY DESIGN

The research strategy is a survey, and the method of investigation is a questionnaire. The flow chart of research methodology can be seen in Figure 1.

The first phase of the research begins with an explanation of the project, identification of problems occurs in the project, and literature review to be able to get a supporting theory basis to solve the problems. The criteria for the need of project management software are obtained from literature review and interviews with several employees involved in the logistics department of the project.

After obtaining the 5 criteria needed the most in a project management software, a matrix comparison is carried out between the criteria to determine the weight of these criteria. The matrix will then be evaluated against 3 to 5 experts to determine the weight of each criterion so that the most criteria according to each expert can be obtained. Each of criteria will be assessed through the scoring methods from 1 – 9. The weight of each criteria will be calculated to rate the top 3 most needed features on project management software at "X" project. Based on these 3 criteria, the scoring and assessment of the alternatives (project management software) will be carried out using the analytical hierarchy process method using Super Decisions software.

7 RESULT AND DISCUSSION

7.1 The Hierarchy of The Research

Before doing all the assessment and scoring for the criteria matrix and project management software decision, the hierarchy of the research must be created to show the goal, criteria, and alternative 8. The analytical hierarchy process of the research can be seen in Figure 2.

7.2 Population and Research Sample

In conducting the research, the sampling technique was carried out by non-probability sampling and the sampling was carried out by purposive sampling. The population is taken from elements of

Table 2: Research Population and Sample

No	Position	Amount
1	Logistic Controller	1
2	Subcontracting Administration	1
3	Import Department Staff	1
4	Superintendent	1

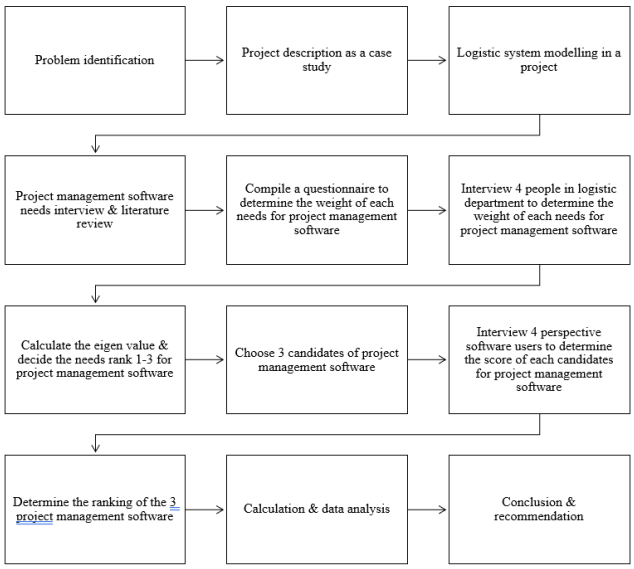

Figure 1: Research Methodology

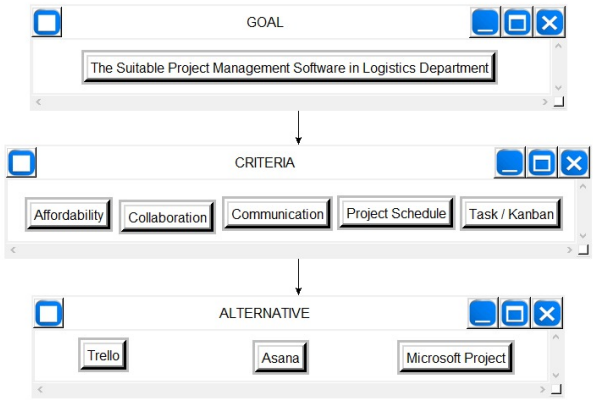

Figure 2: Analytical Hierarchy Process of Research Methodology

logistics department team as many as four people as per on Table 2. The four selected people are representatives from each department in logistics in the project considering that there are quite a lot of logistics member so it will be difficult to conduct interviews with almost all members.

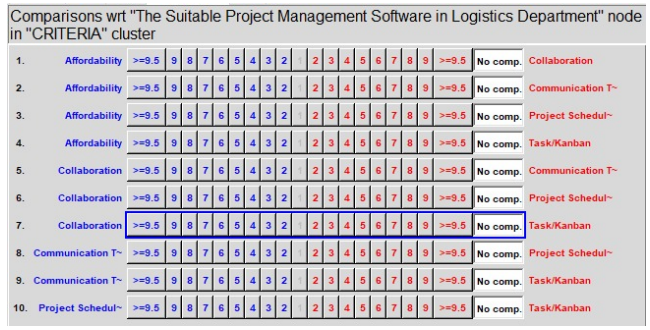

Figure 3: Criteria Matrix Questionnaire on Super Decisions

7.3 The Criteria Matrix and Scoring Result

The matrix of each criteria is done and Figure 3 showing the five criteria matrix on SuperDecisions software.

Scoring and assessment carried out by the four interviewees from numbers 1 – 10 based on the importance of each matrix of five criteria. Consistency of each scoring should be calculated. If the value is more than 10%, then the data assessment judgment must be corrected. Repeated assessment and scoring should be carried out until the consistency value reaches less than or equal to 0.1 [18]. The assessment and rank of each matrix of the five criteria by four interviewees can be seen on Table 3 with each consistency ratio of 0.1.

On this calculation, the project schedule is prioritized the most, where all member team should be able to update all the activities schedule to keep it on track. Next rank is collaboration criteria, it is used to plan, coordinate, control, and monitor distributed all the complex activities without any face-to-face interaction. The core elements of a project collaboration platform are email, document sharing, group calendar, team collaboration and real-time collaboration (stream, chats, forums). Task / Kanban criteria is on rank 3, it is designed to help visualize work, limit work-in-progress, and maximize efficiency. Expected that all the team members be able to update, see, and track the progress of all tasks in many projects on one board.

7.4 Project Management Assessment

All the three candidates of the project management software are being scored on each these three most important criteria, which are project schedule, collaboration, and task or Kanban. The three most important criteria were selected so that the assessment of these software candidates will be more focused and according to the demand from perspective users who work in logistics department

Table 3: The Weight and Rank of The Criteria

	The Weight				Average of The Weight	Rank
	1	2	3	4		
Affordability	0.1130	0.0359	0.1136	0.0308	0.0733	4
Collaboration	0.2763	0.1579	0.2731	0.0948	0.2005	2
Communication	0.0581	0.0501	0.0355	0.0775	0.0553	5
Project Schedule	0.5113	0.5086	0.5241	0.5062	0.5125	1
Task / Kanban	0.0414	0.2475	0.0536	0.2907	0.1583	3

Table 4: The Weight of Three Candidates PM Software in Project Schedule Criteria

	The Weight				Average of The Weight
	1	2	3	4	
Trello	0.0703	0.0726	0.0654	0.1659	0.0936
Asana	0.3496	0.2521	0.1994	0.0698	0.2177
Microsoft Project	0.5801	0.6752	0.7352	0.7644	0.6887

Table 5: The Weight of Three Candidates PM Software in Collaboration Criteria

	The Weight				Average of The Weight
	1	2	3	4	
Trello	0.0833	0.3333	0.1994	0.3537	0.2424
Asana	0.1932	0.3333	0.0654	0.0904	0.1706
Microsoft Project	0.7235	0.3333	0.7352	0.5559	0.5870

Table 6: The Weight of Three Candidates PM Software in Task / Kanban Criteria

	The Weight				Average of The Weight
	1	2	3	4	
Trello	0.7014	0.0612	0.0698	0.1994	0.2580
Asana	0.2132	0.7231	0.1659	0.0654	0.2919
Microsoft Project	0.0853	0.2157	0.7644	0.7352	0.4502

directly on the project. Table 4, Table 5 and Table 6 show the scoring and assessment of three candidates of project management software on each three most important criteria from four respondents.

It shows that Microsoft Project rather than other candidate software based on the Analytical Hierarchy Process calculation was selected to be in the first rank with each score:

- Project schedule is 0.6887 It has highest score rather than others because the software is integrated with other Microsoft software, it's showing more detailed on the features, it can create and determine the WBS on each tasks, it's be able to add the duration and constraints on each tasks, it's be able to define tasks relationship, and it's be able to set the status date to show the percentage of completion.
- On the collaboration criteria, it scores 0.5870. This score is also superior to the other two software because of the ability of Microsoft Project which is not only designed to track progress but also to support collaboration and make it easy to manage all aspects of a team project, including file sharing, chats, meetings, and much more. This is very important considering that all team members work in their own home, so it is very difficult if you don't use a document sharing platform. Other Microsoft software such as Microsoft Teams and Office 365 can be used to be the sharing platforms within the team members.
- On the task / Kanban criteria, it scores 0.4502. Although this score is not too high than the assessment on other criteria, but still Microsoft Project is still in the first position on this criterion to other two software. Microsoft Project also provides Kanban board to let you view and manage your existing task projects. Any other additional information also

can be added such as task ID, resources, duration period and also the percentage work completion.

To be in summarized, the reasons of Microsoft Project was ranked to be number one according to the three important criteria can be detailed described as follows:

1. It is the pioneer of all project management software and a well-known software for every people from various companies
2. It provides more detailed features on some several features such as project schedule and Kanban board
3. It is integrated with other Microsoft software, such as teams, outlook, sharepoint, onedrive to support the work
4. The affordability criteria are not so important considering that the cost of subscribing of Microsoft Project is the most expensive compared to others.
5. The company has paid all the Microsoft package since the project had been started, but hasn't being utilized optimally

8 CONCLUSION AND RECOMMENDATION

8.1 Conclusion

Based on the result of the research that has been done it can be concluded that:

- Criteria used or determining the rank of project management software consist of project schedule, collaboration, and task / Kanban. Other criteria such as affordability and communication were not included from the user's perspective, these two criteria are not so important and can be replaced by other criteria
- Microsoft Project, based on the result of analytical hierarchy process assessment, was selected to be the first rank rather than other two software. However, this software hasn't being utilized optimally, considering the company already own it, integrated with other Microsoft package since the project started, so it is highly recommended for the company to encourage Microsoft Project utilization

8.2 Recommendation

Recommendations that can be given for the companies are as follows:

- Maximize the use of project management software during the implementation of working from home
- Develop programs and task force to encourage project management software utilization in the company
- The programs should include:
- Socialization regarding the use of project management that will be used so that all team members can be more aware of the benefit of using it
- Workshop about how to utilize the whole project management software that will be used

Recommendation that can be given for the companies are as follows:

- Further study from human factors point of view:
- How to encourage employee to use the project management software?
- How to elaborate the utilization of the project management software that will be used with another department?
- Further study from performance management point of view:
- Measuring the effectiveness of using the project management software to the project performances
- Finding the influencing factors of using the project management software to the whole project quality and performances

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REFERENCES

[1] Project Management Institute, Project Management Institute, Newtown Square: Project Management Institute, 2008.
[2] K. H. Rose, Project Quality Management: Why, What, and How, Florida: Ross Publishing Inc, 2005.
[3] H. Cicibas, O. Unal and K. A. Demir, "A Comparison of Project Management Software Tools (PMST)," *Proceedings of the 2010 International Conference on Software Engineering Research & Practice,* vol. 2, 2010.
[4] H. M. Gharaibeh, "Developing a Scoring Model to Evaluate Project Management Software Packages Based on ISO/IEC Software Evaluation Criterion," *Journal of Software Engineering and Application,* vol. 7, no. 1, pp. 27-41, 2014.
[5] S. Hansen, "Study on the Management of EPC Projects," *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development,* vol. 5, no. 3, pp. 11-22, 2015.
[6] D. Hodgson, "Disciplining the Professional: The Case of Project Management," *Journal of Management Studies,* vol. 39, no. 6, pp. 803-821, 2002.
[7] P. J. Jackson and J. M. Van Der Wielen, Teleworking: International Perspectives from Telecommuting to the Virtual Organisation, London: Routledge, 1998.
[8] S. Kadarsah and R. M. A, Sistem Pendukung Keputusan, Bandung: PT Remaja Rosdakarya, 1998.
[9] F. Kinsman, The Telecommuters, New York: John Wiley & Sons, 1987.
[10] J. Kundu, T. K. Bishoi, M. Bhattacharya and A. Chowdhury, "Project Management Software - An Overview," *International Journal of Current Innovation Research,* vol. 1, no. 6, pp. 129-135, 2015.
[11] B. Kutlu, A. Bozanta, E. Ates, S. Erdogan, O. Gokay and N. Kan, "Project Management Software Selection Using Analytical Hierarchy Process Method," *International Journal of Applied Science and Technology,* vol. 4, no. 6, pp. 113-119, 2014.
[12] E. E. Potter, "Telecommuting: The Future of work, corporate culture, and American society," *Journal of Labor Research,* vol. 24, pp. 73-84, 2003.
[13] V. Siddhartha and C. Malika, "Telecommuting and Its Effect in Urban Planning," *International Journal of Engineering Research and Technology,* vol. 5, no. 10, pp. 448-453, 2016.
[14] S. M. Siha and R. W. Monroe, "Telecommuting's Past and Future: a Literature Review and Research Agenda," *Business Process Management Journal,* vol. 12, no. 4, pp. 455-482, 2006.
[15] Y. S. Soedarsono, Kamus Istilah Proyek, Jakarta: Elex Media Komputindo, 2008.
[16] I. Soeharto, Manajemen Proyek (dari Konseptual sampai Operasional), Jakarta: Erlangga, 2001.
[17] Software Advice, "Asana vs Trello," 2006. [Online]. Available: https://www.softwareadvice.com/project-management/asana-profile/vs/trello/. [Accessed April 2021].
[18] S. Sudarto, "Pemanfaatan Analytical Hierarchy Process (AHP) sebagai Model Sistem Pendukung Keputusan untuk Pemilihan Karyawan Berprestasi," *Jurnal Sifo Mikroskil,* vol. 12, no. 1, pp. 11-20, 2011.
[19] T. I. Susilo, Kisah-Kisah Membangun Industri di Indonesia, Jakarta: PT XYZ, 2007.
[20] C. Trihendradi, Microsoft Project 2010, Pendekatan Siklus Proyek Langkah Cerdas Merencanakan & Mengelola Proyek, Yogyakarta: Penerbit ANDI, 2011.

Decision making for the person in-charge of designing a new ball mill machine project using Analytic Network Process (ANP) case of Chukoh Seiki Co., Ltd., Japan

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ABSTRACT

In making a decision, it is necessary to have factors or accurate comparisons. The research was conducted to select the person in charge of the new project design within the company using the Analytic Network Process (ANP) method where this method will use existing factors based on experience and work periods for each design. The decisions given are based on questionnaires obtained from respondents of industrial practitioners engaged in the industrial world, especially design engineering and development. The results are processed in a program called a superior decision. From the results of data processing, it was found that as the person in charge of the project is INA 1 had to improve communication in Japanese so that it was fluent in a job.

CCS CONCEPTS

• **Applied Computing**; • **Operation research**; • **Decision analysis**; • **Multi-criterion optimization and decision-making**;

KEYWORDS

Analytic Network Process, Super Decisions, decision making, ball mill machine

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1 INTRODUCTION

The development of the industrial revolution 4.0 makes industry players to continue to innovate and improve systems in their companies. The 4th (fourth) generation of the Industrial Revolution is marked by the presence of super computers, smart robots, driverless vehicles, editing and genetics as well as the development of neurotechnology that allows humans to further optimize brain function [1].

Chukoh Seiki Co., Ltd. is a fabrication company engaged in the manufacture of ball mill, tube mill and crushing mill machines, in Gifu, Japan. Ball mill is a cylindrical tool used to grind and mix raw materials and rotates on a horizontal axis, partially filled with the material to be milled plus grinding media [2]. Every year the number of requests for machine orders in the company is relatively increasing, accompanied by orders for other parts. Therefore, to support and balance order requests from customers, adequate tools and manpower must be available. One of them is design engineering as a benchmark for starting a new project/making new machines.

At Chukoh Seiki Co., Ltd. there are several design engineers who have different experience backgrounds. In addition, the existing design engineering consists of Japanese and foreigners (Indonesian). Each engineering design has its own job which has a different lead time as well. A leader in a new project should consider who is in charge of the project. This determination is made so that it is right on target and can speed up the work to be done. In determining the person in charge of this work, the Analytic Network Process (ANP) method will be used.

The Analytic Network Process (ANP) method is used because it is considered capable of representing the level of interest of various parties by considering the inter-criteria at the level of structure and sub-criteria. There are two types of linkages in the Analytic Network Process (ANP) method, namely the interrelationships between the same elements (inner dependence) and the interrelationships between different elements (outer dependence) [3].

2 LITERATURE REVIEW

The Analytic Network Process (ANP) method is the development of the Analytical Hierarchy Process (AHP) method. The ANP method is able to improve AHP's weaknesses in the form of the ability to accommodate linkages between criteria or alternatives [4]. The procedure for creating the Analytic Network Process (ANP) is explained as follows:

- Develop a decision model structure

In this step, the problem must be structured and a conceptual model must be created. Initially the important components must be identified. The top most element (cluster) is decomposed into sub-components and attributes (nodes).

- Pairwise comparison matrix of interrelated variables

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Table 1: The fundamental scale of absolute numbers

Intensity of important	Definition	Explanation
1	Equally Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgement slightly favour one activity over another
5	Strong Importance	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Reciprocals of above	The values between two adjacent consideration values. If activity i gets one point compared to activity j, then j has the opposite value compared to i

In the ANP, pairwise comparisons of elements within each level are performed against the relative importance for their control criteria. The correlation matrix is based on a ratio scale of 1 - 9. Table 1 is used to determine the ratio [5]. When a judgment is made for a pair, the reciprocal value is automatically assigned to the inverse comparison in the matrix. After the pairwise comparison is complete, the vector corresponding to the maximum eigenvalues of the constructed matrix is calculated and the priority vector is obtained. The priority value is found by normalizing this vector. In the assessment process, problems can occur in the consistency of pairwise comparisons. The consistency ratio provides a numerical assessment of how much this evaluation may be inconsistent. If the calculated ratio is less than 0.10, the consistency is considered satisfactory.

1. Supermatrix calculation
   After the pairwise comparison is complete, the supermatrix is calculated in 3 steps
   a. Unweighted Supermatrix (unweighted supermatrix)
   b. Weighted Supermatrix (weighted supermatrix)
   c. Composition of the Limiting Supermatrix
2. Weight of importance of clusters and notes

Determination of the importance weights of the determinants using the finite-supermatrix results from the ANP model. The overall priority of each alternative is calculated through the synthesis process. The results obtained from each subnetwork are synthesized to obtain the overall priority of the alternatives.

3 METHODOLOGY

In collecting research data, researchers used the method of literature study, respondent selection, and questionnaires.

1. Study literature: The method in which to get the data is taken from literature, journals, textbooks, and other sources that are in accordance with the material taken.
2. Respondents: In this case, the selection of respondents is very important, in collecting respondents there are at least 6-8 people. The selection of respondents themselves can be from experts, practitioners or other regulators. In filling out the questionnaire, it will be assisted as much as possible in order to get balanced results.
3. Questionnaire: Questionnaires are made in order to obtain appropriate data, make questionnaires that can be understood by respondents so that there are no gaps in filling out the questionnaire.

4 RESULT AND ANALYSIS

In the preparation of this study using a questionnaire to obtain information data that will be used for calculations. By using the existing criteria in the company, a questionnaire was made to determine priorities in determining the person in charge of the new project design using ANP (Analytic Network Process). As for the provisions, namely the criteria that have been determined from the main criteria and factors in the criteria, an alternative is also added as a comparison sample. Where the results will be used for data processing using Super Decision software shown in Figure 1.

The analysis process using ANP will be explained as follows:

1. Determine the criteria and factors to be used
2. Create a questionnaire

To determine the priority of the existing criteria and factors, as well as alternatives for comparison. In this study, we tried to take a sample of several questionnaires to obtain the desired data. Keynotes come from industry practitioners who work in the field of design engineering and development.

1. Define the model for the criteria

Data is collected and can be calculated using the supermatrix method so that a hierarchical model can be determined from each criterion or it can also be referred to as a cluster. Table 2 describes the cluster of the hierarchy model.

1. Data input process
2. Doing calculations

The data that has been obtained is processed on temporary data to get the combined matrix value which will later be inputted in the software.

2. Perform data input to software

The data that has been processed is inputted into the existing program, namely Super Decision to determine the priority of the criteria and the priority of the alternatives used.

Table 2: Cluster

No	Criteria	Factor in criteria	No	Criteria	Factor in criteria
1	Experiance	Job mastery	4	Project experiance	Ball mill
		Software mastery			Tube mill
		Problem solving			Crushing mill
2	Communication	Mastery of language	5	Project on hand	0-1 project
		Teamwork			1-2 projects
3	Work periods	1 Month-6 Months			1-3 projects
		6 Months - 1 Year	6	Alternatives	Employee JPN 1
		1 Year - 2 Years			Employee JPN 2
					Employee JPN 3
					Employee INA 1

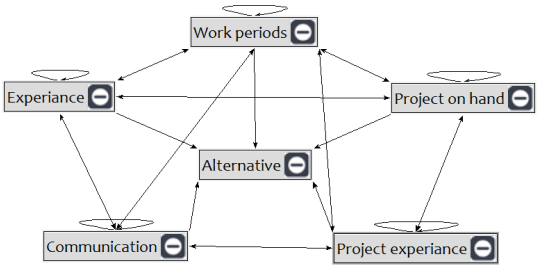

Figure 1: ANP model

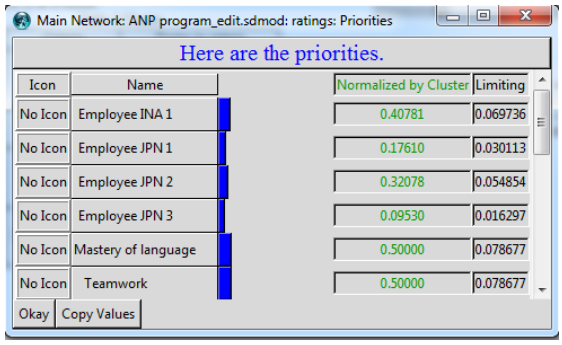

Figure 2: ANP Result

After entering the results of the questionnaire into the super decision program, the following results will be obtained shown in Figure 2. The priority in the selection of the person in charge of the new design and other factors can be seen with the largest number.

5 CONCLUSIONS

From the results of data processing using Super Decision software with the ANP (Analytic Network Process) method, it can be explained that the person in charge of the new project is INA 1 with a score of 0.407. However, because of the importance of Japanese language skills in the selection of this case, it is recommended to improve ability to communicate in Japanese. Because INA 1 employees are still lacking in communicating in Japanese. And for other designs, it is necessary to try project design with assistance first because most of them have mastered the software used and have previous design experience. For this research, it is far from perfect. In the future, it is necessary to improve the questionnaire for respondents in order to get maximum and balanced results.

REFERENCES

[1] Astuti, S. A. (2018). Impact of Industrial Revolution 4.0 and the Utilization of Digital Media Technology towards Siber Community Behavior. Proceeding of Community Development, Volume 2.

[2] Jagadeesh, P., Yuvaraj, M., Yuvaraj, R. and Sasikumar, S., 2018. *Fabrication of low cost ball milling machine.* EPH-International Journal of Science And Engineering (ISSN: 2454-2016), 1(1), pp.336-342. Ihsan Yu¨ksel a, M. D. (2007). Using the analytic network process (ANP) in a SWOT.

[3] Oktaviani, A., Wijayanto, D. and Prima, F., *Penentuan Supplier Terbaik Menggunakan Metode Analytic Network Process (ANP).* Jurnal TIN Universitas Tanjungpura, 4(1).

[4] Saaty, T. L. (1999, August 12-14). FUNDAMENTALS OF THE ANALYTIC NETWORK PROCESS. ISAHP 1999

[5] Saaty, T. L. (2008). Decision making with the analytic hierarchy process. Int. J. Services Sciences, Vol. 1.

Implementation of Single Minute Exchange of Dies at PT Ganding Toolsindo

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ABSTRACT

PT Ganding Toolsindo's problem is the replacement of the die which takes a long time, around 30 to 45 minutes per setup. The strategy that can be used to reduce setup time is to apply the Single Minute Exchange of Dies (SMED) method. This research aims to identify the cause of the high die replacement time on the SEYI SN2-300 Press Machine and take corrective steps to increase production effectiveness on the machine, as well as design jigs and fixtures that can make it easier for operators to replace the die. Results Based on data collection on setup dies activity on the SEYI SN2-300 Press Machine, all entered into the internal setup activity with a duration of 2144 seconds. Changes from an internal setup to an external setup have been made. Changing from internal setup to external setup can reduce downtime by 369 seconds. The design of the tools in the form of hanging rollers and roller die is expected to reduce the machine's internal setup time, where these tools can assist operators in moving old dies and installing new dies into the press machine. Based on the measurement of setup time after the implementation of the tools made, the results showed that there was a decrease in setup time of 331 seconds or 5.52 minutes..

CCS CONCEPTS

• **General and reference** → Document types; Reference works.

KEYWORDS

die replacement, single-minute exchange of dies, jig, and fixture design

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*Place the footnote text for the author (if applicable) here.

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1 INTRODUCTION

The increasingly fierce level of competition in the industry requires companies to have competitive advantages, such as higher quality products and faster service. Companies that can satisfy their customers with faster and quality product delivery will have an advantage over their competitors. Faster service can be done by optimizing value value-added and minimizing non-value-added activities.

PT Ganding Toolsindo is an automotive component manufacturing company that was founded in 1998 by Ir. H. Wan Fauzi. The company develops in the manufacture of machine parts, stamping parts, assembly parts, molds, and dies, as well as fixtures and jigs. PT Ganding Toolsindo is faced with a competitive lead time challenge. The problem faced by the company is that there are still non-value-added activities such as death reimbursement which takes a long time around 30 to 45 minutes per setup. The process of replacing the die can reach 3 (three) times.

One approach that can be taken to reduce setup time is to apply the Single Minute Exchange of Dies (SMED) method. This concept was introduced by Shingo in 1960 which was a strategy to speed up die replacement setup [1]. The application of this method can reduce setup time in various industries. This study aims to identify the cause of the dead repair time on the SEYI SN2-300 Press Machine and take the following steps to increase production effectiveness on these machines, through the implementation of SMED, as well as the design of tools that can make it easier for operators to carry out the die replacement process

2 LITERATURE REVIEW

Lean is an effort that is made continuously to eliminate waste and increase the added value of products (goods or services) to provide value to customers (customer value) so that it is appropriate to achieve a perfect work flow to minimize waste and be flexible or change the process [2]

In the Lean approach there are five principles [3]:

1. Identify what provides value and what does not from the customer's point of view and not from the perspective of the organization, function, or department.

2. Identify the steps required to design, order, and produce along the value-added process for the wastage flow. 3. Make value-added activities flow without distractions, flipping, or waiting.

4. Make what the customer only asks for.

5. Striving for perfection continuously reduces wastage.

The latest research that focuses on the implementation of SMED, among others, is Mulyana and Hasibuan [4] proving that the application of the SMED method in the process of setup or changeover

activities in the production of telecommunication panels has reduced the downtime of punching machines from 44.90 hours to 10.96 hours or a decrease in time of 75.59%. The SMED method is applied to the Palestinian Aluminum Profile Company to reduce the time of dies changing when manufacturing aluminum profiles. The results show that the implementation of SMED can result in savings ranging from 5%-15% in running costs while increasing production capacity [5].

Implementation of the Single Minute Exchange of Dies (SMED) and Maynard Operation Sequence Technique (MOST) Methods for Improvements has been carried out at PT. X Surabaya to improve the production process time. The SMED method is applied at the setup time of changing the production of one type of model to another. The result of applying the SMED method is a reduction in setup time from 3410 seconds to 2627 seconds or 43.5%. While the MOST (Maynard Operation Sequence Technology) method is used to measure based on the order of the sub-activity or movement. Improvements made include inventory area made with line 2 area so that it can take 780 TMU, laying material so that time can be eliminated by 1920 TMU, placing shrink package so that it can increase the time by 960 TMU [6].

Reducing dies replacement time on the 75-ton Nouguchi press machine was carried out at PT. Implement Prosperous Engineering. The method used is the SMED (Single Minutes Exchange of Die) method. Improvements were made to overcome the problem of handling dies from the storage area to the machine area which has a longer distance. The stages of improvement carried out are improving work procedures and designing trolley die tools. The reduction in time obtained after the repair process is 30% or 571 from the initial time of 1885 seconds to 1314 seconds. The reduction in time is expected to increase the effectiveness of production at PT. Laksana Teknik Makmur [7].

Another study on the use of the SMED method in the metal-working industry was conducted by Monteiro, et al. This research aims to reduce waste and increase productivity in the machining department. The steps taken are problems and processes using flow charts and VSM (Value Stream Mapping). The improvements made succeeded in reducing setup time by 40% on vertical milling machines and 57% on horizontal milling machines[8].

The SMED method can also be applied to the pharmaceutical industry to improve output quality and customer satisfaction. The results showed that the application of the SMED method can shorten machine downtime so that production capacity increases. Time reduction from the application of the SMED method by 30% within 12 months [9].

Another alternative to reduce setup time is to use a jig and fixture. The use of jigs & fixtures makes it easier to work on the manufacturing process to get higher product quality or higher production rates [10]. In designing jigs and fixtures, things need to be considered, including convenience, security and user comfort, and the process of making the materials used [11].

3 RESEARCH METHODOLOGY

The research method used is direct observation in the field. During the dies replacement process, recording is carried out so that the operator's time and activity data can be known from the recorded video. The implementation of SMED starts from the identification of the internal setup activities and the external setup activities in the washer component production process 1. The stages of the research process can be seen in Figure 1.

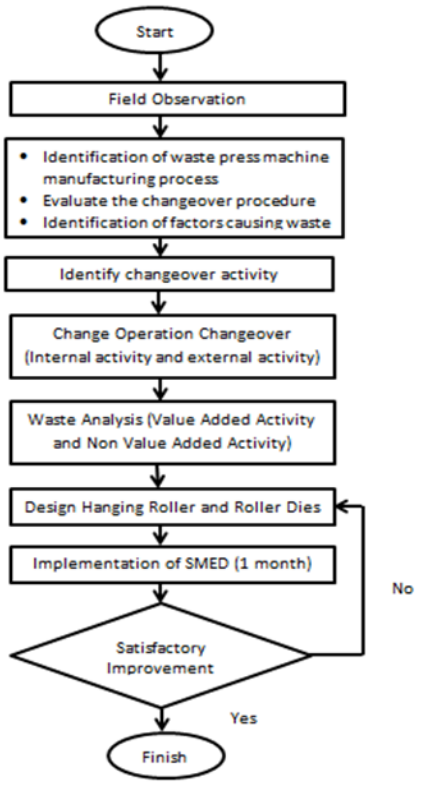

Figure 1: Stages of the Research Process

4 FINDING AND DISCUSSION

4.1 Setup Time Calculation

Field observations were carried out by observing the activity of replacing dies. Measurement of the time required for each machine setup activity by going through the video recording of the SEYI SN2-300 Press Machine setup activity. Based on the measurement results of the setup process, the total time required to setup dies on the SEYI SN2-300 Press Machine is 2144 seconds or 35.73 minutes.

4.2 Identification of Internal Setup and External Setup Activity

The internal setup activity is a dies replacement activity carried out by stopping the machine/process and checking the first product, while the external setup activity is a setup activity carried out without stopping the machine (initial preparation and completion). Identification of the activities of the internal setup and external setup can be seen in Table 1.

Based on field observations, all die setup processes carried out on press machines are carried out in a machine stopped condition so that 100% of setup activities are included in the downtime category,

Table 1: Identification of Internal Setup and External Setup Activity

No	Activity	Type	Time (s)
1	Lowering upper dies	Internal	6
2	Removing the bolt	Internal	107
3	Raising the upper engine base	Internal	14
4	Cleaning the press machine area	Internal	132
5	Waiting for the forklift	Internal	42
6	Lifting dies	Internal	14
7	Block the dies	Internal	4
8	Moving the dies to the dies storage	Internal	61
9	Taking new dies for the stamping washer 1 process using a crane	Internal	80
10	Lifting the dies to the press machine by using a forklift	Internal	94
11	Set the top base height	Internal	239
12	Fixing bolts for fastening the dies on the machine	Internal	654
13	Make sure the dies are set properly	Internal	27
14	Taking material for stamping washer components 1	Internal	161
15	Installing the material from the washer 1 component to the coil feeder machine	Internal	41
16	Attaching the material to the coil feeder machine to the press	Internal	74
17	Place the reservoir for the remaining pieces of production material (scrap)	Internal	26
18	Putting the base and the power button	Internal	18
19	Conduct trial production and check the quality of washer components 1	Internal	350

where total downtime = total setup time is 35.73 minutes. In 1 day there are 3 (three) die setup activities, so the total dies setup time is 3 x 35.73 minutes = 107.19 minutes/day and the whole process is an internal setup which will be downtime for the company, which is 1, 79 hours/day. While the time required to produce 1 unit of washer 1 component, where the process takes 1 stroke is 2 seconds, then if the loss experienced by the company is 107.19 minutes/day or 6431.4 seconds/unit divided by processing time 1 washer is 2 seconds/unit, so the result is 3215.7 or about 3215 units which will be lost because that time is the time when the machine is stopped.

4.3 Change of Internal Setup Activity to External Setup Activity

Changing the internal setup activity to an external setup activity requires improvements to the system and the way the operator works. With these changes, it is hoped that some internal setup activities can be carried out while the machine is still operating or turned into an external setup. Changes in internal activity to external setup can be seen in Table 2.

In Table 2, it can be seen that there are changes in some of the internal setup activities to become external setups according to the observation of the die replacement activity on the SEYI SN2-300 Press Machine so that the downtime on the SEYI SN2-300 Press Machine is reduced by 369 seconds, so the current downtime is 1775 seconds with a downtime percentage of 82.79%.

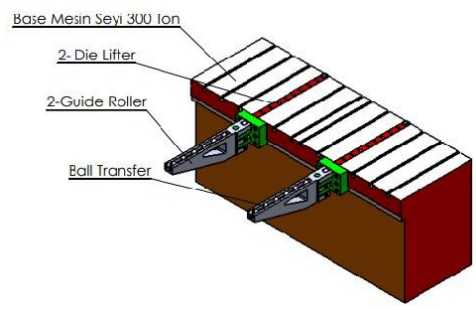

Figure 2: Hanging Roller Design

4.4 Analysis of The Causes of High Internal Set-up Activity

Analysis of the factors causing high machine down time and internal setup activity time using the 5W+1H method as shown in Table 3.

4.5 Reduce the time of internal activity setup

To assist the process of moving the old dies to the dies storage area and transferring the new dies to the press machine, work aids were designed in the form of hanging rollers and roller dies which can be seen in Figure 2.

Figure 2 is a design drawing of the hanging roller tool. This tool is made of iron with a roller in the middle.

Table 2: Change of Internal Setup to External Setup

No	Activity	Type	Description
1	Lowering upper dies	Internal	
2	Removing the bolt	Internal	
3	Raising the upper engine base	Internal	
4	Cleaning the press machine area	Internal	
5	Waiting for the forklift	Internal	
6	Lifting dies	Internal	
7	Block the dies	Internal	
8	Moving the dies to the dies storage	Internal	Can be done by operator 2
9	Taking new dies for the stamping washer 1 process using a crane	Internal	Can be done by non-production operators
10	Lifting the dies to the press machine by using a forklift	Internal	
11	Set the top base height	Internal	
12	Fixing bolts for fastening the dies on the machine	Internal	
13	Make sure the dies are set properly	Internal	
14	Taking material for stamping washer components 1	Internal	Can be done by non-production operators
15	Installing the material from the washer 1 component to the coil feeder machine	Internal	Can be done by non-production operators
16	Attaching the material to the coil feeder machine to the press	Internal	
17	Place the reservoir for the remaining pieces of production material (scrap)	Internal	Can be done by operator 2, while operator 1 does production trial
18	Putting the base and the power button	Internal	
19	Conduct trial production and check the quality of washer components 1	Internal	

Table 3: Analysis of the factors that cause high machine downtime and internal setup time

No	What	Where	When	Why	Who	How
1	The length of the process of letting go bolt	Press Machine	The year 2021	Bolts are still used conventional	Operator	Replace it with a clamp bolt (no use thread)
2	There is a process of cleaning the press machine area	Press Machine	The year 2021	The existence of work equipment and goods that are not needed	Operator	Workplace settings with 5S
3	There is an activity waiting for a forklift	Press Machine	The year 2021	Dies to be transferred using forklift	*Forklift Driver*	Replacing forklifts with cranes
4	The dies removal process takes quite a long time starting from lifting, propping, lifting the dies,	Press Machine	The year 2021	The process of removing the dies is assisted by a forklift and shifting it to the center of the machine using a crowbar	Operator and F*orklift Driver*	Design and build work tools in the process of moving dies

Figure 3: Hanging Roller Fixing

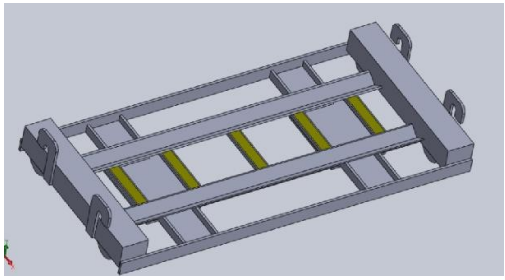

Figure 4: Roller Dies Design

Figure 5: Roller Dies Fixing

Figure 3 is a picture of a hanging roller workpiece. This tool is used as a place to walk the wheels or function like train tracks. The existence of a roller will make it easier for the wheel when pushed.

Figure 4 is a design drawing of the roller dies tool. This tool is made of iron with wheels.

4.6 SMED Implementation

Based on the results of measuring the time of moving the dies with the tools of hanging rollers and roller dies, the time needed to move the dies can be seen in Table 4.

4.6.1 Measurement of Dies Displacement Time. Based on the results of measuring the time of moving the dies with the tools of hanging rollers and roller dies, the time needed to move the dies can be seen in Table 4

Table 4: Process Time for Old Dies Transfer

No	Activity	Type	Time (s)
1	Setting chains and chain hangers	Internal	47
2	Lifting the dies pair and placing them on the dies roller	Internal	32
3	Putting the dies on the dies roller which is above the hanging roller	Internal	13
4	Unleash the chain	Internal	12
5	Pushing the dies into the press	Internal	17

Table 5: Process Time for Old Dies Transfer

No	Internal Activity	Type	Time (s)
1	Setting chains and chain hangers	Internal	47
2	Lifting the dies pair and placing them on the dies roller	Internal	32
3	Pulling the dies onto the hanging roller	Internal	18
4	Setting chains and chain hangers	Internal	47
5	Picking up a couple of dies	Internal	32
6	Putting the dies on top of the storage		15
7	Unleash the chain		12

The total time to transfer the dies to the press is 121 seconds. In the same way, the process of moving old dies can be done, which can be seen in Table 5.

Based on the calculation results, the total time for the setup dies on the SEYI SN2-300 Press Machine is 1945 seconds or 32.42 minutes or a difference of 2144 seconds − 1813 seconds to 331 seconds or 5.52 minutes.

5 CONCLUSION AND FURTHER RESEARCH

Based on the analysis of the results of this study, the following conclusions can be drawn:

1. Dies setup activity on the SEYI SN2-300 Press Machine based on observations, all enter into the internal setup activity where in this condition the machine is in a state of being unable to produce/stop, resulting in a down time of 2144 seconds.
2. Changes from internal setup to external setup have been made for activities to move the dies to the dies storage area, take new dies for the stamping washer 1 process using a crane, pick up material for stamping washer 1 component, install material from washer 1 component to the coil machine

feeder, and placing scrap storage tanks for the rest of the production material (scrap) where this activity can be carried out by non-production operators so as not to interfere with the work of production operators.

3. Changes from internal setup to external setup can reduce downtime by 369 seconds.
4. The factors causing the high machine setup time are due to the long process of removing the bolts, the process of cleaning the press machine area, the activity of waiting for the forklift, and the process of moving the dies takes a long time starting from lifting, blocking, lifting the dies.
5. The design of the tools in the form of hanging rollers and roller die is expected to reduce the machine's internal setup time, where these tools can assist operators in moving old dies and installing new dies into the press machine.
6. Based on the measurement of the setup time after the implementation of the tools made, the results showed that there was a decrease in setup time of 331 seconds or 5.52 minutes.

Suggestions that can be given in this research are:

1. Based on the trial process carried out on the implementation of the use of hanging rollers and roller dies, several problems occur, namely the hanging roller swings while pushing the dies, and the roller dies have not moved smoothly from the hanging roller to the bolster, and the hook chain does not exist, for that stage, the next trial and improvement are still being done to strengthen the setup process with the help of these work tools.
2. From the last conclusion shows that the decrease in setup time is only 5.52 minutes, this happens that the longest internal setup activity is in removing the bolts on the old dies and tightening the bolts on the new dies. can reduce the processing time.
3. Suggestions for further research is to make a useful tool to speed up the process of installing bolts

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REFERENCES

[1] Shingo, S. (1985). A Revolution in Manufacturing The SMED System. CRC Pers.
[2] Liker, J. K., & Morgan, J. M. (2006). The Toyota way in services: The case of lean product development. Academy of Management Perspectives, 20(2), 5–20. https://doi.org/10.5465/AMP.2006.20591002
[3] Gaspersz, V. (2007). Lean Six Sigma for Manufacturing and Service Industri. Gramedia.
[4] Mulyana, A., & Hasibuan, S. (2017). Implementasi Single Minute Exchange of Dies (Smed) Untuk Optimasi Waktu Changeover Model Pada Produksi Panel Telekomunikasi. Sinergi, 21(2), 107. https://doi.org/10.22441/sinergi.2017.2.005
[5] Assaf, R. (2017). An Application of Single Minute Exchange of Die Approach in an Aluminum Profiles Extrusion Production System: Case Study. International Journal of Scientific Research and Innovative Technology, 4(7), 2313–3759. https://www.researchgate.net/publication/319019018
[6] Wibowo, W., Dwi, A., & Lukmandono. (2021). Implementasi Metode Single Minute Exchange of Dies (SMED) dan Maynard Operation Sequence Technique (MOST) untuk Perbaikan Waktu Proses Produksi (Studi Kasus Departemen Produksi-Wrapping di PT . X Surabaya). Senastitan, 1.
[7] Maldini, G., Yuselin, N., Gaya, J., Raya, M., Ii, S., Utara, J., Astra, P. M., & Masalah, P. (2019). Pengurangan Waktu Proses Penggantian Dies Di Mesin Press 75 Ton Nouguchi Untuk Meningkatkan Kapasitas Produksi Di PT. Laksana Tekhnik Makmur. Technologic, 10, 1–11.
[8] Monteiro, C., Ferreira, L. P., Fernandes, N. O., Sá, J. C., Ribeiro, M. T., & Silva, F. J. G. (2019). Improving the machining process of the metalworking industry using the lean tool SMED. Procedia Manufacturing, 41, 555–562. https://doi.org/10.1016/j.promfg.2019.09.043
[9] Karam, A. A., Liviu, M., Cristina, V., & Radu, H. (2018). The contribution of lean manufacturing tools to changeover time decrease in the pharmaceutical industry. A SMED project. Procedia Manufacturing, 22, 886–892. https://doi.org/10.1016/j.promfg.2018.03.125
[10] Arifin, F. (2018). Jig and Fixture. Kompasiana, (September), 1–13. https://www.b-on.pt/Conference Name:ACM Woodstock conferenceConference Short Name:WOODSTOCK'18Conference Location:El Paso, Texas USAISBN:978-1-4503-0000-0/18/06
[11] Fajar, A. N., Safera, I., Hustnusawab, M., & Sumpena, A. (2015). Rancang Bangun jig and fixture Sebagai Pemosisi Bor Tangan. Seminar Nasional Teknik Mesin, 175–180.

Application of Six Sigma in Quality Improvement of Deodorant Products at PT Cedefindo

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KEYWORDS

PT Cedefindo is a chemical manufacturing company with one of its products in the form of Deodorant lotion sachets. The company's quality standard with defects per unit (DPU) per shift is 1%. Based on data from June-August 2021, the average DPU of this product is 3.69% and a DPMO value of 3,952, so this research is necessary to reduce the number of defects. The six-sigma method is applied to improve quality. The highest defects occurred in the sealing process with four types of defects, they are seal join, seal damage, seal crooked, and perforation. Based on the analysis, the most dominant defects are seal joins and seal damage. The problem is the lack of operator skill to set up the machine, the lack of operators on the production floor, and the operator's lack of understanding of the SOP. The best improvement to be proposed to the company is making a work assessment form and a checklist of work instructions for operators. The improvement could not be implemented due to the pandemicSig sigma, DMAIC, Quality Improvement

MOTS CLÉS

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1 INTRODUCTION

Quality control is a technique and activity to achieve, maintain, and improve the service quality of a product [1]. Services or products of good quality will meet consumer expectations for these [2]. Quality has a correlation with purchase intention, purchase decision, customer satisfaction, and customer trust [3]. Quality improvement can be useful for building networks in product marketing [4]. Several factors affect quality control, they are process capability, applicable specifications, acceptable levels of non-conformance, and quality costs [5].

PT Cedefindo is a contract manufacturing company under the Martha Tilaar group. This company is engaged in cosmetic products, hair and body care, perfumes, and household cleaning products. This company is a third party that performs the production and packaging process. One of the products from this company is Deodorant. This product was chosen as the object of research because it has the highest number of orders volume compared to other products.

Based on data from June to August 2021, the number of defects and defects per unit for each month that shown in Table 1. The inspection process was conducted randomly and sampled every hour. The defect limit per unit set for the entire product produced in one shift is 1%. So that if there is a shift that results in the number of defects per unit being more than this value, then the entire production will be held in advance for sorting one by one.

Based on data, the average defect per unit produced is 0.0369, or a value of 3.69%, which is above the tolerance limit. The high number of defects resulted in causing the detention of production so that the number of requests did not fulfill on time. Table 2 shows the number of defects for each deodorant production process. Sealing is the highest contributor to the number of defects. Therefore, this research will focus more on that process.

Table 1: The number of defects and defects per unit

Month	Sample	Defect	Defect per unit
June	10272	407	0.0396
July	13728	520	0.0379
August	10440	349	0.0334
Average			0.039

Table 2: The number of defects for each process

Month	Batching	Cutting	Sealing	Filling	Wrapping
June	17	13	361	0	16
July	15	2	463	0	40
August	4	9	296	0	40
Total	36	24	1120	0	96

Six Sigma with DMAIC (Define, Measurement, Analyze, Improvement, dan Control) methodologies focuses on continuous improvement and assists in process optimization by identifying the cause of the defect [6] [7]. A defect is defined as anything outside of customer specifications [8].

Many studies on quality control have been done. Quality control of Plastic PP Corrugated Box Manufacturer used the DMAIC method that the cause of defects consists of several factors, namely human factors, and machine operators poorly trained [9]. The implementation of six sigma with the DMAIC method to reduce defects in packaging has also been done in the flour industry [10]. Six sigma applications with DMAIC are also widely used in the production process.

Based on these problems, this paper aims to identify defects in the sealing process, determine factors that cause defects, and corrective actions to reduce the number of defects in this product. This effort is to reduce potential losses and client dissatisfaction with the company.

2 METHODOLOGY

Data used in this research from June to August 2021 at PT Cedefindo. This research used DMAIC (Define, Measurement, Analyze, Improvement, dan Control). DMAIC is used to improve product quality and reduce the number of defects. DMAIC is a process of continuous improvement towards Six Sigma targets. The DMAIC phase is a phase that repeats or forms a quality improvement cycle with Six Sigma [11].

2.1 Define Phase

This phase used the SIPOC and Critical to Quality (CTQ) diagrams. The SIPOC (Supplier, Input, Process, Output, and Customer) diagram is a high-level process map that is useful for describing the stakeholders involved in the production process. CTQ is a critical variable that is needed in the use of the Six Sigma method that focuses on the needs of consumers.

2.2 Measure

At this phase, create a control chart. The control chart is a graphical display used statistically control running process quality. In this research, the quality characteristics of the company cannot be measured attributes. Then, the data taken for quality control purposes is in the form of the number of nonconformities in the overall product produced from each shift. In addition, the number of samples taken each day varies due to differences in the amount of production carried out. Thus, the U control chart was used in this research.

$$U = \frac{c_i}{n_i} \tag{1}$$

$$UCL = \bar{U} + 3\sqrt{\frac{\bar{U}}{n_i}} \tag{2}$$

$$LCL = \bar{U} - 3\sqrt{\frac{\bar{U}}{n_i}} \tag{3}$$

Defects per Unit (DPU), is a calculation that describes the average number of defects of the entire sample being inspected (4)

$$DPU = \frac{number\ of\ defects}{sample} \tag{4}$$

Defects per Opportunities (DPO) is a calculation for the average number of defects that occur from all available opportunities (5).

$$DPO = \frac{Total\ defects}{Total\ opportunities} \tag{5}$$

2.3 Analyze

At this phase, this activity determines the main problem causes, estimates the need to achieve the target, and identifies obstacles to achieving the target [5]. Pareto diagrams, Ishikawa diagrams, and Failure Mode and Effect Analysis (FMEA) were used in this phase. FMEA is a tool for determining the priority of the source defect causes in a product or process in the company [5]. The steps for making FMEA are as follows [12]:

- Identify processes, failure factors, and consequences
- Fill in the Severity, Occurrence, and Detection values on a scale of 1-10 for each factor.

Table 3: The number of productions and defects per day

Date	Sample	Defect	Defect per Unit
8/2/2021	576	13	0.0226
8/3/2021	192	6	0.0313
8/4/2021	288	15	0.0521
8/5/2021	288	12	0.0417
8/6/2021	288	51	0.1771
8/7/2021	228	11	0.0482
8/8/2021	288	12	0.0417
8/9/2021	576	14	0.0243
8/10/2021	576	16	0.0278
8/12/2021	576	15	0.026
8/13/2021	288	9	0.0313
8/14/2021	480	11	0.0229
8/15/2021	384	7	0.0182
8/16/2021	384	10	0.026
8/17/2021	672	11	0.0164
8/18/2021	192	9	0.0469
8/19/2021	96	24	0.25
8/20/2021	576	17	0.0295
8/21/2021	480	15	0.0313
8/22/2021	384	19	0.0495
8/23/2021	96	5	0.0521
8/24/2021	576	8	0.0139
8/25/2021	384	5	0.013
8/27/2021	288	5	0.0174
8/28/2021	480	14	0.0292
8/30/2021	228	21	0.0921
8/31/2021	576	12	0.0208
Total	10440	367	0.0352

- Performing Risk Priority Number (RPN) calculations.

2.4 Improve

In the Improve phase, a check sheet is used to record any failures that occur in the running process, complete with a description of the failure, and the steps that need to be taken to fix it.

2.5 Control

Control is the final phase in a Six Sigma quality improvement program. The Control phase is ensuring the new process has implementing [5]. In this phase, Control keeps doing to make sure the quality level of the processes has increased

3 RESULTS

3.1 Define

Based on the results from direct observations on the first shift during August 2021. Table 3 shows the number of productions and the number of defects produced per day.

As shown in Table 3, the number of defects that occurred exceeds the company's quality standard of 1%. Therefore, corrective steps are needed to reduce the level of defects produced in the company. The next step is the SIPOC diagram. The results of the SIPOC diagram analysis are in Table 4.

Based on the production process data, the process that contributes to the highest defect is the sealing process. So, the CTQ identification process is carried out on the In Process inspection of the sealing process with attribute data. The CTQ in the sealing process for this product is shown in Table 5.

3.2 Measure

At this stage, create a U control chart using disability data from four types of CTQ. Based on Figure 1 shows that all data are within the control limits. It illustrates that the entire process in August already had good process stability.

Furthermore, conducted the calculation of the capability of the running process. The values of DPU, DPO, and DPMO obtained are 0.0284, 0.0071, and 7088. So that the Sigma Level = 3.952 is obtained. Based on the results of the above calculations, it is known the company production process has a chance to produce 7088 defects one million times. Although the process capability of Deodorant production already has a sigma value above the average industrial sigma value in Indonesia [13], quality improvement is still needed to fulfill client quality standards.

Table 4: SIPOC diagram

Supplier	Input	Process	Output	Customer
Client	Raw Material that has not been inspected	Raw material inspection	Raw Material that passed inspection	raw material warehouse
Raw material warehouse	Raw material that passed inspection	Weighing of raw materials	Raw Material ready to be mixed	FEM Machine 1000
FEM Machine 1000	Raw Material ready to be mixed	Raw Material Mixing	Bulk Material in container	Filling and Packing room
Filling and Packing room	Bulk Material in container	Pumping into the Mespack Machine	*Bulk Material* in Mespack Machine	Mespack Machine
Raw material warehouse	Reel Sachet and spout	Loading material to Mespack Machine	Spout dan reel sachet in Mespack Machine	Mespack Machine
Mespack Machine	Reel sachet, spout, and Bulk Material in machine	Sachet batching, sachet reel cutting, sachet sealing, product filling and spout installation	Filled, sealed and spout-mounted sachets	Ulma Machine
Ulma Machine	Flow rap and sachet	Sachet packing in flow map and flow map cutting every 12 pcs sachets	Deodorant products	Zelda Machine
Raw material warehouse	Fibrate	Forming of fibrate into boxes by Lantech 1 machine	Fibrate formed	Zelda Machine
Zelda Machine	Deodorant Lotion Series and box	Folding and packing in boxes	Fibrate contains 12 series of deodorant lotions	Lantech Machine
Zelda Machine and warehouse	Fibrate containing product and duct tape	Fibrate Gluing	Glued Fibrates	Client

Table 5: The CTQ of Deodorant Product

Defect Type	Descriptions
Seal Damage	This defect occurs when the seal on the product is damaged, such as the seal position is tilted or not at the seal position
Seal join	This defect occurs when the position of the sachet is not straight so that the seals coincide with each other.
Seal Crooked	This type of defect occurs when the seal on the product is bent, concave, or not in a straight line.
Perforation	Type of defect occur when the sachet has a hole so that the product inside leaks out.

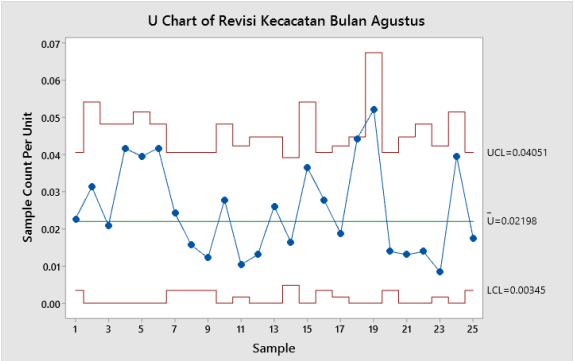

Figure 1: U control chart

3.3 Analyze

The analysis is determining the cause of the defect to decide on corrective steps to be implemented. The first is to create a Pareto chart. The number of defects used in create the Pareto Chart by sorting the data. Based on Figure 2, shows the highest defect types are Seal Join and Seal Damage, with a percentage of 48.6% and 31.4%. Thus, these two types of defects become a priority for analysis regarding the factors that cause defects and corrective steps that can be taken to reduce the number of defects produced.

The next step is to conduct an analysis related to the factors that cause disability. The analysis process uses a fishbone diagram. Figure 3 and Figure 4 shows the results by using fishbone diagrams for seal joins and seal damage.

The results of the analysis from the Ishikawa diagram are used in FMEA as a potential cause at the production stage. In this step,

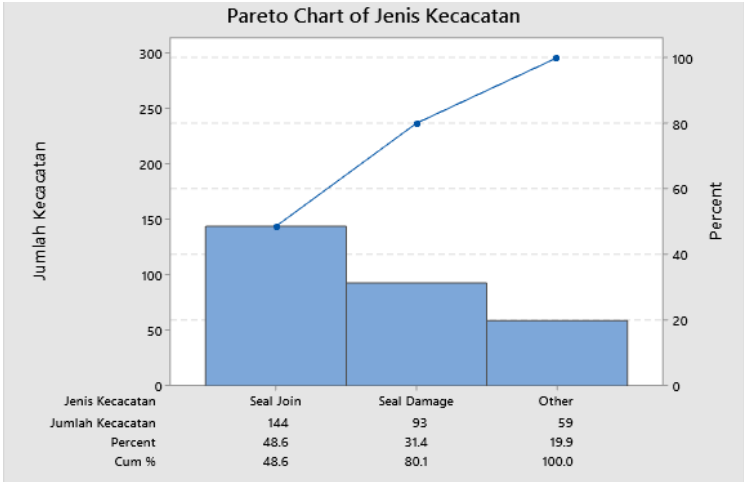

Figure 2: Pareto chart

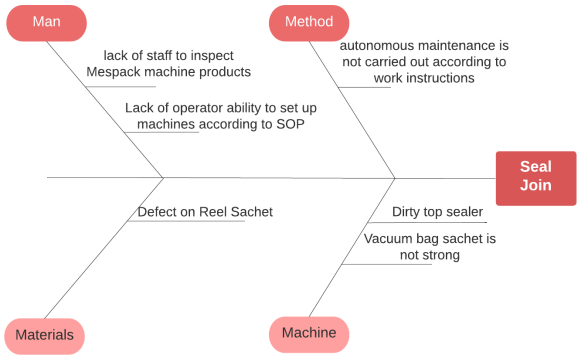

Figure 3: Fishbone diagram for seal join

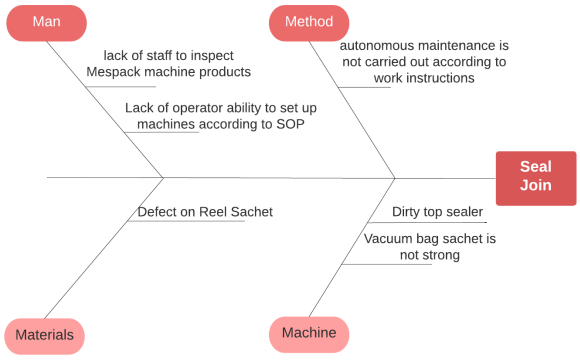

Figure 4: Fishbone diagram for seal damage

each factor will be assessed with Severity (S), Occurrence (O), and Detection (D) factors based on the results of interviews with the company. The results of filling out the FMEA are shown in Table 6 below.

3.4 Improve

The priority causes of the defect are seal joint and seal damage. The problem is the lack of operator skill to set up the machine, the lack of operators on the production floor, and the operator's lack of understanding of the SOP. Thus, brainstorming has been done with the company to plan alternative improvement proposals aimed at minimizing the potential for failure. The first alternative is the addition of the Number of Operators. Because seal joint and seal damage, as well as the lack of operators on the production floor, provides information that additional operators are needed to supervise the sachet products produced by the Mespack machine.

Based on the number of shifts, production lines, and operator needs, the total costs are determined as follows.

Total Cost = UMR x Number of Operators
= IDR 4,700,000 x 18 Operators
= Rp. 84,600,000/month

The second alternative is Providing Training to Operators. The operator does not have sufficient ability to set up and maintain the machine. So, it is necessary to train operators to improve operator knowledge related to it. The training planned by Plant Engineering for six months. In addition, the training also invites experts as presenters every two weeks to deepen the knowledge of the operators.

The details of the costs required for this activity are as follows.

Total Training Cost = Total Training x Training Cost
= 36 x IDR 800.000
= IDR 288,000,000

The third alternative is Making Work Assessment Check sheets and Checklists Work Instructions for Operators. The other suggestion that can be given is to improve the operator's ability. It is to assess the operators on the production line. That is because there is a possibility that there were operators have different skills so not all of them require the same training.

Table 6: FMEA

Process	Potential Failure-Mode	Potential Effect ofFailure	S	Potential Cause	O	Current Control Prevention	D	Risk PriorityNumber
Sealing	Seal Join	Lowering the level of product quality so it did not accept for client quality standards.	10	The operator did not setup the machine according to the SOP	9	Not Yet	9	810
				Insufficient number of operators to monitor Mespack machines	9	Operators who are not busy will monitor temporarily	7	630
				Autonomous maintenance is not carried out according to the Work Instructions	5	Use of checklists and checks by the team leader.	2	100
				Defective Reel Sachet	5	Incoming material inspection	1	50
				Vacuum bag sachets are not strong enough	3	Weekly Preventive Maintenance	3	90
				Top Sealer dirty	4	Periodic maintenance	2	80
				Operator does not understand SOP	8	Not yet	8	640
				The installation of the sachet reel is not appropriate or not straight	6	Monitoring by supervisor or production leader	1	60
	Seal Damage			Spout defects	5	Incoming material inspection	1	50
				Sucker open bag worn	4	Weekly Preventive Maintenance	2	80
				Incorrect sealer temperature	3	Calibrate	2	60

The performance appraisal sheet is needed to obtain data related to the current capabilities of operators so that if the training is implemented, it will be more in line with the operator's requirement and right on target for operators who are still less capable.

In addition, another obstacle for the company is that there are still many operators who do not understand SOPs and work instructions, even though SOP sheets and work instructions are located on each machine. Thus, that suggested providing a checklist sheet to each operator. With this checklist sheet, the operator will be able to know the work step without repeatedly checking the SOP and work instructions located on the machine. That will make it easier for supervisors to check the location of the error, especially if there are machines problem.

The alternative of Making Work Assessment Check sheets and Checklists Work Instructions for Operators was chosen to apply in this company. The reason is that have minimum cost requirements, can be used easily by operators, can improve process performance, supports increased operator capabilities, and can be relied upon to provide data related to the current condition of workers.

3.5 Control

The next step is to prepare selected improvement for the company and follow up on the results of the implementation with the following design as seen at Table 7.

However, cause of the pandemic at the time, this plan could not be implemented. The emergence of a policy from the company that

Table 7: Implementation plan

Activity	Implementation of Work Assessment Check sheets and Checklists Work Instructions
Reason	To assess operator performance and make it easier for operators to setup machines according to work instructions
Location	PT Cedefindo
Person In Charge	Plant Engineering Supervisor
Period	Two Weeks
Requirement Data	- Work Instruction Checklist that has been filled in by the operator - Work assessment form that has been filled out by the supervisor - Production quantity data - Data on the number of production defects
Implementation Steps	- Supervisor performs operator performance appraisal - Operators with sufficient or less scores will be paired with operators with good or very good scores - Operators who have sufficient or less ability will be given training according to their needs for two weeks - The operator is given a checklist of work instructions and asked to fill out the checklist when setting up the machine for two weeks - Collecting data on the number of production and the number of defects produced after two weeks of implementation - Calculate process stability with U control chart and production process sigma level - Comparing the stability and capability of the process before and after improvement to see if implementation can reduce the number of defects produced

restricted outsiders from entering the factory. Some things that can use to improve product quality are as follows:

Following up on the work assessment results from the operator with the technical ability to work with sufficient or less skill will be given training according to the operator's needs.

Pairing operators with good technical ability skills with operator's technical ability is sufficient or less so they can help each other.

Doing routine calculations with control charts and sigma levels to ensure that the processes are in a stable condition and there is an increase in the process quality.

The supervisor routinely checks the work instructions checklist of each operator to ensure that the operator carries out all work instructions.

Monitoring the production floor to ensure operators work according to standard procedures and work instructions.

4 CONCLUSIONS

Based on the results, there are four types of defects in the sealing process, seal joint, seal damage, seal crooked, and perforation. The DPMO value obtained is 3,952. The most dominant types of defects are seal join and damage seal, with incidence percentages of 48.6% and 31.4%. The problem is the lack of operator skill to set up the machine, the lack of operators on the production floor, and the operator's lack of understanding of the SOP. The best improvement to be applied to the company is making a work assessment form and a checklist of work instructions for operators. The improvement could not be implemented due to the pandemic. For further research it should involve other factors, such as cost and other types of waste found on the production floor

REFERENCES

[1] D. H. Besterfield, Quality Control, USA: Pearson Education, 2009

[2] H. Tannady and Y. Maimury, "Increasing the Efficiency and Productivity in the Production of Low Voltage Switchboard Using Resource Constrained Project Scheduling," *Journal of Industrial Engineering and Management (JIEM),* vol. 11, pp. 01-33, 2017.

[3] E. Pitaloka and H. Tannady, "Analysis of citizen satisfaction on National Agency of Drug and Food Control of Republic Indonesia (NADFC)," *Technology Reports of Kansai University,* vol. 62, pp. 1069-1075, 2020.

[4] C. G. Karno and E. Purwanto, "The effect of cooperation and innovation on business performance," *Quality Access to Success,* vol. 18, pp. 123-126, 2017

[5] D. C. Montgomery, "Introduction to Statistical Quality Control, USA: John Wiley & Sons, 2009

[6] G. Sundaramali, K. S. R., S. Anirudh, R. Mahadharsan and S. K. S, "Application of DMAIC to Reduce the Rejection Rate Starter Motor Shaft Assembly in the Automobile Industry: A Case Study," *nternational Journal of Industrial Engineering & Production Research,* vol. 32, pp. 1-8, 2021.

[7] H. Kurnia, Setiawan and M. Hamsal, "Implementation of statistical process control for quality control cycle in the various industry in Indonesia : Literature review.," *Operations Excellence: Journal of Applied Industrial Engineering,* vol. 13, pp. 194-206, 2021.

[8] G. Lei, T. Wang, J. Zhu, Y. Guo and S. Wang, "System-level design optimization method for electrical drive systems—Robust approach.," *IEEE Transactions on Industrial Electronics,* vol. 62, pp. 4702-4713, 2015.

[9] H. Tannady and E. Purwanto, "Quality Control of Frame Production Using DMAIC Method in Plastic PP Corrugated Box Manufacturer," *Journal of Physics: Conference Series* , pp. 1-5, 2020.

[10] Yadrifila, A. A. Septyanti and A. M. M. R. Rus, "Implementation of lean-DMAIC method for reducing packing defect in a flour company," in *AIP Conference Proceedings*, 2020.

[11] I. Setiawan and Setiawan, "Defect reduction of roof panel part in the export delivery process using the DMAIC method: a case study," *Jurnal Sistem dan Manajemen Industri,* vol. 4, pp. 108-116, 2020

[12] D. Stamatis, Failure Mode And Effect Analysis: FMEA From Theory To Execution Second Edition, ASQ Quality Press., 2003.

[13] V. Gaspersz, Pedoman Implementasi Program Six Sigma Terintergrasi dengan ISO 9001:2000, MBNQA, dan HACCP, Jakarta: Gramedia, 2003.

Is Interface Quality and Information Quality on Online Review Matters?

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ABSTRACT

The use of e-marketplace in Indonesia has been growing rapidly for the last decade. The practicality has been the main reason for customers to utilize their shopping activity through e-marketplace. This study aimed to identify and investigate the factors influencing customer purchase intention in the context of e-marketplace. Moreover, this study will be divided into two parts. First part is to present a theoretical perspective of literature in the context of customer purchase intention represented by S-O-R theory and Prospect Theory as basic theories to adopting the model. The second part discusses on a conceptual model, which proposed four antecedent factors (interface quality, information quality of online review, enjoyment, and trust) and one moderating variable: risk, that affect customers purchase intention. The result shows that the interface quality of e-marketplace, information quality of the online review, enjoyment and trust have positive effects towards customer purchase intention. Meanwhile, relationship between trust and purchase intention does not moderate by risk. This result also implied that customers start to consider the usefulness of interface quality and information quality of online reviews before making a purchase. This study suggests that e-marketplaces should place greater reinforcement on developing quality factors of interface and online review on their platform to promote a positive attitude and behavior of customer. Furthermore, this study will help managers to understand the main factors in the online shopping environment which drives customers purchase intention to increase e-marketplace productivity and efficiency.

CCS CONCEPTS

• **Applied computing** → Electronic commerce; Online shopping.

KEYWORDS

Interface Quality, Information Quality of Online Review, S-O-R theory, Prospect Theory, e-marketplace

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1 INTRODUCTION

The rapid and sprawling development of technology and information in Indonesia facilitates the flexibility economic activities for customers, one of which is online shopping activities. In such kind of condition, customers utilize the use of e-marketplace to assist online shopping activities. The research conducted by Global Data and ISEAS in 2021 showed that Indonesia is one of the countries in South-East Asia with the expansive growth in digital market and digital economy value, with the role of e-marketplace being the driving force for the expansion of growth [1] [2]. According to data from several sources, the value of online purchasing transactions is growing year after year. One of the valuable sources, statistics from Bank Indonesia, revealed that the value of transactions increased from 2017 to the end of 2021. In 2017, the value of transactions was 42,2 trillion IDR, which was positively growing in 2018 and 2019 to 105.6 trillion and 205.5 trillion IDR. Then, it was getting increased at the end of 2020 and 2021 with the value of 266 trillion and 401 trillion IDR [3] [4]. This remark is supported by a 2020 survey conducted by WeareSocial and Hootsuite Report, which revealed that 138.1 billion Indonesians routinely engage in online retail activities [5].

Furthermore, e-marketplace grow in popularity among Indonesian customers for facilitating online purchasing activities at any time and from any location to give customers with ease. According to Nugroho [6] and Apac Outlook Organization [7], there are several main reasons why e-marketplace being massively adopted in Indonesia. First, e-marketplace provides all customers need on one-screen to seek, see, choose, and buy the products directly at one hand. Second, e-marketplace offers accessibility, practicability, and comfortability for the customers to carry out shopping transactions. Third, e-marketplace always offers more attractive promotions and events. Fourth, one of the driving forces is the high internet penetration and connectivity rate.

With the increasing use of e-marketplace in the society, the greatest features for their sites and applications are expected of e-marketplace companies. Hence, this way, the customers can do online transactions more conveniently and easily. Previous studies [8] [9] found out that interface quality and information quality of

online review plays significant roles to affect positive customer behaviors for customers such as trust, enjoyment, and purchase intention. Hence, to attract customers purchase intention, e-marketplace companies are required to ensure the prime information quality of online reviews and good interface quality. The purpose of this study is to explain and gives a comprehensive understanding of how interface quality and information quality of online reviews as a part of e-marketplace environment plays crucial roles in customers' behavior and customers purchasing decision.

2 LITERATURE REVIEW

This study will deploy two models from previous research which investigates the factors that affect customer purchase intention. The first study is the study conducted by Zhu et al. [8]. This study examines a model involving five main variables: information quality of online review, social presence, trust, customer satisfaction, and purchase intention. In this study, the purchase intention became the dependent variable. Zhu et al. [8] utilizes the S-O-R theoretical framework as the basic theory to test the model. The results showed that the quality of information from online reviews and social presence significantly positively affected consumer trust. Furthermore, consumer satisfaction and information quality from online reviews have a significant positive effect on consumer purchase intentions, consumer satisfaction, and consumer trust.

The second study was conducted by Patel et al. [9]. Patel et al. [9] conducted a study which involving four main variables: interface quality, trust, enjoyment, and purchase intention. This study places purchase intention variable as the dependent variable. The model in this study uses the concept of S-O-R theory as the basic theory to test the model. The results showed that the interface quality positively influences enjoyment, trust, and purchase intention. In addition, enjoyment has a significant positive effect on trust and purchase intention. Meanwhile, trust has a significant positive effect on purchase intention. This study aims to fill the gap by adopting and integrating two models from the study of Zhu et al. [8] and Patel et al. [9] to examine purchase intentions. This study involves four independent variables (interface quality of e-marketplace, information quality of online reviews, enjoyment, and trust), one dependent variable (purchase intentions). This study will also add moderating variable (risk) in the model, to examine the relationship between trust and purchase intention. This study will apply the concept of S-O-R theory to test the relationship between variables and prospect theory to test the moderating relationship between trust and purchase intention.

2.1 S-O-R Theory

The conceptual model that developed in this study is constructed based on S-O-R (Stimulus-Organism-Response) Theory. S-O-R Theory was introduced by Mehrabian and Russel in 1974 and developed by Jacoby in 2002 [10]. S-O-R Theory posits that the environmental aspect around customer's (stimulus) could induce cognitive and affective evaluation process in customer's mind (organism). In the end these processes, it could encourage customers to perform certain behavioral response [11]. Furthermore, S-O-R theory has been widely used in various marketing studies to explain customers' behavior in online transactions [12]. The result of these various studies showed that environmental aspects of e-marketplace have a crucial role in nurturing cognitive and affective evaluation processes inside customers' minds and affecting the behavioral response [13] [14]. In this study, S-O-R theory is implemented to adopt research's model and study how e-marketplace features (interface quality and information quality of online review) affect consumers trust, enjoyment, and purchase intention. Based on the aforementioned underpinning research, the interface quality and the online review's information quality will act as a stimulus. Further, the organism process is represented by customers' trust and enjoyment, while the response is represented by the customer purchase intention..

2.2 Prospect Theory

Prospect theory was developed by Kahneman and Tversky in 1979 and was generated from expected-utility theory [15]. In prospect theory, it argues that individual can be affected by cognitive bias when they make decisions in uncertain situations [16]. The theory also emphasizes that individual tends to consider social and psychological factors when making decision in uncertain condition [17]. Prospect theory suggests that individuals are sensitive to the framing of gain or loss even when customers are considering whether or not to make a purchase, they are given the same information [18]. This process will lead to a process where individual will choose the best alternatives among many alternatives as the result of the decision-making process [19]. Prospect theory has been extensively applied in numerous marketing studies to examine various customer behavior in context of e-marketplace [20] [21]. In this study, prospect theory is applied to investigate the implications of moderating variable (risk) towards the relationship between trust and purchase intention. Additionally, it is applied since the online shopping activities involved varied of risks while customer conduct the transaction

3 METHODOLOGY

The study employed quantitative analysis method to identify the factors that affecting purchase intention. To collect data from the respondents, a survey instrument was deployed. The survey instrument used Likert scale to measure each item range from 1 ("I strongly disagree with the statement") until 7 ("I strongly agree with the statement). Prior to that, a pilot study was conducted to assess the validity and reliability for each instrument item. It was carried out to fifty samples.

After conducting pilot study, a second study was performed for hypothesis testing and structural model evaluation purpose. In second study, a larger number of samples was collected which was 331 respondents. This study used 31 items to measure all of variables involved in the research model. To measure all constructs in this study, the measurement items from previous studies were adopted and customized in the context of e-marketplace. Measurement items were adopted studies of Aladwani and Palvia [22], Zhu et al. [8], Gefen et al. [23], De Wulf and Iacobucci [24], Moon and Kim [25], Dodds et al. [26] and Kamallul-Arifin et al. [27]. The researcher utilized Google Form to collect the data from respondents. The collected data were checked before it was proceeded for next steps. The researchers received data from 331 respondents. Thus, the response rate for the survey was high since it reached 94.57%. The

acquired data were considered applicable for evaluating the research model and hypotheses testing.

4 DEVELOPMENT OF CONCEPTUAL MODEL AND HYPOTHESES

Bhandari et al. [28] and Patel et al. [9] stated that interface features in e-marketplace being sought as the most important factors that affect customer willingness to buy. In this case, if e-marketplace has the good quality of interface features, it will affect their trust, increasing customer's enjoyment and induce customer's purchase decision since interface features have a major role in assisting customers while doing the online shopping transactions. Another crucial factor that affects customer intentions to buy is the information quality of online review [29] [30]. Thus, online reviews are being sought by the customers as the first most credible and dependable sources of information before customers make a purchase decision. This is caused by dissemination of information in online review tend to be more detailed. Also, online reviews are derived from the experiences of other consumers who have purchased so that it is more dependable than other methods of information that companies frequently supply as part of a marketing plan [31]. Customers tend to look for online review information that is complete, reliable, easy to understand and assist them in purchasing decisions [29]. Consequently, the information quality of online review also plays a crucial role in affecting customers purchase intention.

Aside from that, good interface quality and excellent information quality of online reviews are essential factors that affect positive behaviors of customers, such as trust and enjoyment [8] [9]. Good interface quality will give customers a favorable view of the e-marketplace. This will affect customers to build a high feeling of trust in the competence and integrity of the e-marketplace to conduct online shopping transactions. On another side, good interface quality will also positively affect enjoyment. Bruner et al. [32] stated that if the interface quality of the e-marketplace is categorized well, for instance, it does not intimidate customers in the process of use and is easy for customers to adapt it quickly, providing a high feeling of enjoyment for the customer. Moreover, the excellent information quality of online reviews will also affect trust. Cheung et al. [33] mentioned that if customers feel that information quality of online review affects customers' perceptions of the reliability of the information implied in the online review. When customers' perceptions of the reliability of information increase and they perceive that the quality of the information in online reviews tends to be more credible, this will positively affect customers' trust [34]. Previous studies also mentioned that both trust and enjoyment also play a significant role to purchase intention since both factors give the feeling of ease of use and assure customer to conduct online shopping transactions safely and comfortably [35].

4.1 Interface Quality

Interface quality defined as the excellence quality of design and features of e-marketplace while customers using the interface features to carry out online shopping transactions [36]. Hassanein and Head [37] mentioned that interface quality of e-marketplace can manipulate the customers' perceptions so they will feel positive experience towards online shopping activities if the interface quality of e-marketplace is considered good enough. These good perceptions will navigate customers to trust the e-marketplace and will affect customer's intention to buy. Therefore, in this study, interface quality will serve as a stimulus since it can influence customers' attitudes and behaviors regarding online buying activities. Various studies have confirmed that interface quality will affect trust [38]. This is because the interface quality substitutes the offline store atmosphere while users conduct transactions [39]. Therefore, if interface quality of e-marketplace is seen as having a good appearance, structured and complete information, and easy for consumers to use the interface features, then consumers will feel trust towards e-marketplace. This is because customers will reduce their risk perception while conducting the transactions as the interface quality could accommodate the online shopping transactions smoothly [40]. Interface quality also will help customers to understand the whole process of online shopping transactions [41]. Hence:

Hypothesis 1 (H1): Interface quality of e-marketplace positively affects trust.

Previous studies showed that research has shown that high interface quality gives significant impact towards enjoyment of customer [42]. Interface quality of e-marketplace evidenced to have a beneficial impact on customer positive behavior such as enjoyment [43]. Moreover, Choi and Lee [44] claimed that good interface quality of e-marketplace will influence affective attitude and behavior of customer, such as a sense enjoyment once customer interact with the interface features. Enjoyment is seen as a key factor that motivates people to engage in online buying. Thus:

Hypothesis 2 (H2): Interface quality of e-marketplace positively affects enjoyment.

Aside from trust and enjoyment, previous studies showed that interface quality will affect customers purchase intentions [45]. This is because interface quality will generate emotional valence for customers [46]. According to Cui and Guo [31], an interface's quality will also affect how easily and effectively customers can complete online shopping, enhancing their desire to make purchases from e-marketplace. In the context of online shopping, when customers feel that e-marketplace shows a great quality of interface, it will automatically increase their involvement in online shopping activities. Their active involvement also will increase their buying intentions [47]. The interface quality of e-marketplace evidenced to be an influencer for purchasing behavior in a beneficial way. In other words, interface quality has a significant effect on the customer purchasing intention. Therefore:

Hypothesis 3 (H3): Interface quality of e-marketplace positively affects customer purchase intention.

4.2 Information Quality of Online Review

Information quality of online review is a description of the extent in which the information in the online review is useful and helpful for customers in making purchase decision [48]. In fact, information quality of online review has become a necessity for e-marketplaces because of the enormous influence they have on customers in terms of information sources [49]. Because the information quality of online review is so crucial in the online buying environment, it will serve as a stimulus in this research model. Previous research confirmed that information quality of online review will have positive

and strong influence towards customers trust [50]. Information quality of online review will help customers to identify the features and comprehend performance of the product, thus, it eases potential consumers to adjust the function of the product to the needs that they want to fulfill [51]. Aside from that, the information quality of online reviews will have convincing impacts on consumers, resulting in trust. Hence:

Hypothesis 4 (H4): Information quality of online review positively affects trust.

Various studies have shown that information quality of online review also have impact on purchase intention [52]. When considering purchasing things from an e-marketplace, potential customers prefer to acquire information and compare that information. Thus, information quality of online review helps consumers to evaluate alternative products and helps consumers in making purchasing decisions [53]. Additionally, research done by Obiedat [54] confirmed that information quality of online review plays a significant role in customer purchase decision and increasing the value of sales. Therefore:

Hypothesis 5 (H5): Information quality of online review positively affects customer purchase intention.

4.3 Trust

In this study, trust is defined as customer confidence perception towards e-marketplace and other customers who provides online reviews [55]. Trust also believed having a role in decreasing the risk perception of customer while conducting online transaction [56]. In this research, trust will have a role as organism process. This is caused by trust being considered as a process which involves affective and cognitive facets in customer's mind [57]. As S-O-R that has been reviewed before, organism process is an evaluation process in customer's mind that involves cognitive and affective aspect. In that situation, because trust creates cognitive and affective assessment processes, trust will operate as an organism process in this study. Previous studies confirmed that trust has a crucial effect on customer intention and behavior. One of the positive effects that caused by trust is purchase intention [58]. Customers are more likely to purchase from e-marketplace if they believe that e-marketplace can provide their needs and exceed their expectations when they do online shopping transactions [59]. Thus, trust is also considered by customers as a parameter that could reduce the risk and concerns in online shopping. Hence:

Hypothesis 6 (H6): Trust positively affects customer purchase intention.

4.4 Enjoyment

Enjoyment is the enjoyable and pleasurable impressions that customers will experience when using e-marketplace to shop [60]. Elwalda et al. [61] confirmed that enjoyment is one form of user's intrinsic motive to use e-marketplace. Customers will have a stronger sense of enjoyment when purchasing online if customers feel that the experience that they get from shopping transaction brings certain pleasure and excitement beyond their expectations [62]. Various marketing studies shows that enjoyment will stimulate customer positive attitude and behavior towards online shopping transaction [63]. In this study, enjoyment will act as organism process. This is because enjoyment represents cognitive and affective process in customer's mind [64]. Research in marketing has shown that enjoyment is a strong predictor for purchase intention [65]. It is because enjoyment regard as the driving force behind experience buying. The experience itself is the source of the value that enjoyment provides, which is one of the reasons individuals engage in online shopping—specifically, so that they can enjoy the experience while performed online shopping transactions [66]. Enjoyment will encourage customer to carry out certain behaviors or habits such as purchase intention [67]. Yoo and Kim [68] stated that to increase customer's purchase intentions to shop online, e-marketplace providers must be able to create an online shopping environment that can produce an enjoyable experience for consumers. Hence:

Hypothesis 7 (H7): Enjoyment positively affects customer purchase intention.

4.5 Moderating Effect of Risk

Risk is defined as the potential for unpredictability and undesirable outcomes for customers as a direct result of their decision to engage in activities related to online shopping [69]. Risk has been reviewed as one of determinant that affect purchase decision making for customer, since it causes loss [70]. Customers think that online shopping through e-marketplace is riskier than buying in physical stores because of the internet's open and sophisticated character, as well as the fact that online purchasing technology is beyond the customers' control [71]. Besides, through online shopping activities, the customers are unable to evaluate the product (for both quality and physical condition) before making a purchase [27]. Furthermore, Lăzăroiu et al. [72] argued that risk is viewed as a measurement of unanticipated dissatisfaction and disappointment with purchase decisions based on the buy objective. Hence, it is a powerful predictor of customer behavior since consumers are more likely to avoid potential failures and losses while carried out online shopping transactions. In this study, risk acts as a moderating variable that can either diminish or strengthen the relationship between trust and purchase intention. Prior to marketing studies, particularly in the context of online shopping, risk is reviewed as one of the strongest moderating variables influencing consumer purchase intentions and behavior [73]. Therefore:

Hypothesis 8 (H8): Risk moderates the relationship between trust and customer purchase intention.

4.6 Purchase Intention

Purchase intention is interpreted as the willingness of customer to buy the products from e-marketplace [74] [75]. In this study, if the purchase intention of customers is getting higher, so it influences the chance of customers to buy products [76]. Bedi et al. [60] mentioned that purchase intention reflects the strongest antecedent of the actual purchase behavior. Since the actual behavior is too difficult to measure, some researchers stated that it is very common to measure behavioral intentions as a substitute for measuring consumer behavior [77]. In this study, purchase intention represents the role of dependent variable and response. The previous studies showed that purchase intention is interpreted as customers'

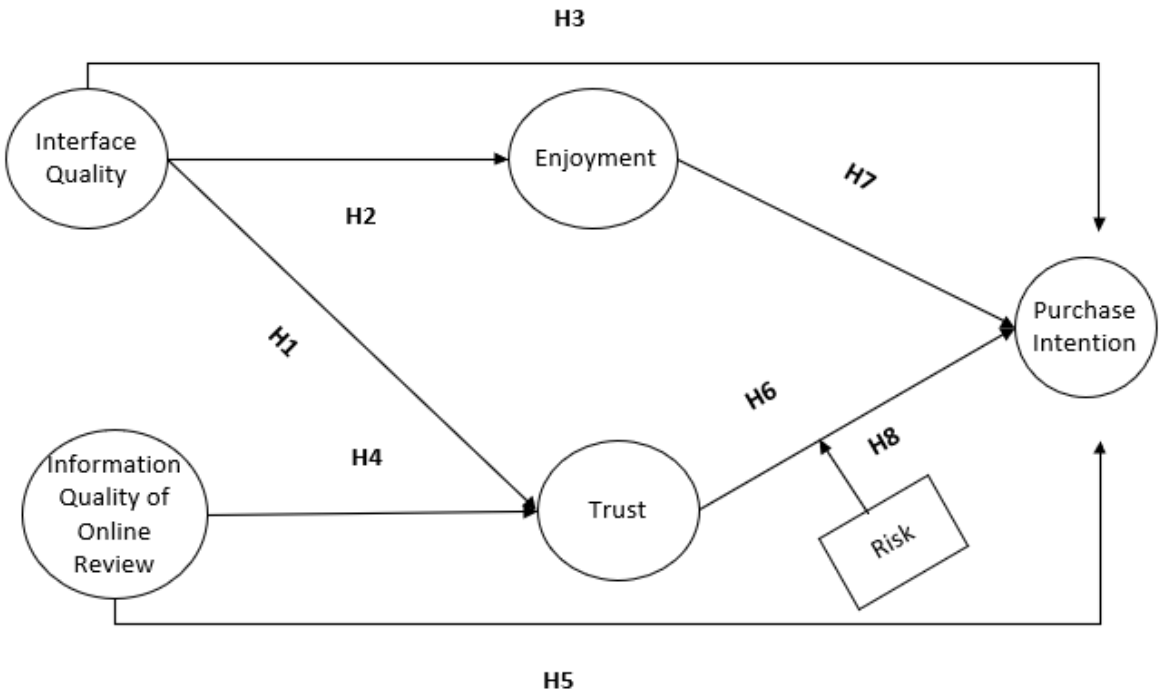

Figure 1: Research Model

choices and outcomes of the S-O-R process [78]. The development of research model in this study shown in Figure 1 below:

5 RESULTS AND DISCUSSIONS

5.1 Demographic Profiles of Respondents

In this study, the demographic profile of respondents was gathered. Based on the gender, a total of 70.1% surveyed participants were female, while 29.9% were male. In addition, 39.9% of the population exist in in DKI Jakarta, whereas 19.9% lived in Bandung. Additionally, a total of 62.8% participants were in the range between 17 and 25 years old. Furthermore, a total of 44,1% participants had completed high school, while 52,9% were college students. Regarding annual income and monthly expenses, 54.5% of participants earned more than IDR 6,500,000 and 35.6% spent more than IDR 5,000,000. The most often purchased skincare items were facial wash (51,2%), sheet masks (49.2%), and serum (48.1%). In addition, 41.1% of participants also selected Innisfree as their preferred brand. Most participants (56.2%) made between four and six purchases annually in a year. Approximately 50,2% participants spent between IDR 250,001 and IDR 500,000 on a one-time purchase.

5.2 Data Analysis

This study utilized IBM SPSS 15.0 and SEM AMOS to examine the obtained data. To measure the outer model, convergent validity, discriminant validity and reliability of the outer model were reviewed. There are two standard approaches to assessing the convergent validity of the outer model. First, loading factors for each measurement item is greater than 0.5. Second, the value of Average Variance Extracted (AVE) should exceed 0.5 [79]. Based on the Confirmatory Factor Analysis (CFA), one measurement item to measure trust, it did not match the criteria and was therefore removed from the list. Thus, the result for AVE values for each construct was in satisfactory, thus, it showed that the measurement model attained convergent validity. It shown in Table 1 below:

Table 1: Result for Convergent Validity (AVE)

Construct/ Variable	AVE
Interface Quality	0.707
Information Quality of Online Review	0.628
Trust	0.733
Enjoyment	0.614
Purchase Intention	0.645
Risk	0.641

Generally, discriminant validity is often tested by determining if the correlations between pairs of construct items depart considerably from unity. Hair et al. [79] argued that constructs have sufficient discriminant validity if the square root of the AVE is bigger than the correlations between the construct and other constructs in the model. In this study, three methods to measure reliability were also evaluated. Hair et al. [79] stated that the constructs concluded as reliable if the value of Cronbach Alpha and Composite Reliability greater than 0.7, meanwhile the value of AVE is exceeding

Table 2: Result for Discriminant Validity (Square-Root AVE)

	Interface Quality	Information Quality of Online Review	Trust	Enjoyment	Purchase Intention	Risk
Interface Quality	**0.841**					
Information Quality of Online Review	0.635	**0.792**				
Trust	0.424	0.564	**0.856**			
Enjoyment	0.542	0.485	0.420	**0.784**		
Purchase Intention	0.550	0.543	0.428	0.498	**0.803**	
Risk	-0.141	-0.162	-0.235	-0.370	-0.141	**0.801**

Table 3: Result for Reliability (Cronbach Alpha, Composite Reliability and AVE)

Construct/ Variable	Cronbach Alpha	Composite Reliability	AVE
Interface Quality	0.924	0.950	0.707
Information Quality of Online Review	0.890	0.930	0.628
Trust	0.816	0.842	0.733
Enjoyment	0.813	0.825	0.614
Purchase Intention	0.843	0.843	0.645
Risk	0.876	0.914	0.641

0.5. Furthermore, the result of discriminant validity and reliability which reviewed valid (discriminant) and reliable shown in Table 2 and Table 3 below:

In addition, R-Square also was reviewed in this study to evaluate the variance of independent variable towards dependent variable. The results revealed that the variances of trust, enjoyment, and purchase intention were at 0.361, 0.427, and 0.539. Respectively, the results indicated that the structural model has a strong ability to predict purchase intention. Meanwhile, the variances of moderating effect of risk towards trust and purchase intention is at 0.06 which is considered as at low. After evaluating outer model, goodness of fit was also assessed in this study. The CFA model demonstrates convergence and reasonable fit for research model, with a low X2 per degree of freedom (3,651) and excellent results for the other fit indices (with CFI 0.848, RMSEA 0.090, GFI 0.759, NFI 0.803, TLI 0.828, PGFI 0.627, and PNFI 0.709). Finally, the overall fit indices of the SEM model suggest a good match with the data.

Since the outer model and goodness of fit were assessed, hypotheses testing analysis can be performed to test each hypothesis in this study. The research model was evaluated using the bootstrapping method and 331 samples to test eight hypotheses in this study. The results demonstrated that SOR theory was accepted for research model. Interface quality positively affects trust, as indicated by a critical ratio value of 2.537 and estimated value of 0.298 ($p<0.05$) for trust, supporting Hypothesis 1. On the other hand, a critical ratio value of 9.736 and estimated value of 0.721 ($p<0.05$) were determined for the effect of interface quality on enjoyment. This result led to H2 being supported. In addition, the results indicated that interface quality positively influenced purchase intentions, with a critical ratio value of 2.697 and estimated value of 0.288, thus supporting Hypothesis 3 ($p<0.05$). The critical ratio value of 4.955 and estimated value of 0.740 ($p<0.05$) supports the hypothesis 4 which mentioned that the information quality of online reviews positively affects trust. In the meantime, with a crucial ratio value of 3.050 and estimated value of 0.373 ($p<0.05$), the information quality of online reviews had a positive and statistically significant influence on purchase intention, supporting Hypothesis 5. With a critical ratio of 1.986 and estimated value of 0.099 ($p<0.05$), trust positively influenced purchase intentions, supporting hypothesis H6. In addition, enjoyment had positive effect on purchase intention with critical ratio of 3.463 and estimated value of 0.266 ($p<0.05$). As a result, this finding supports Hypothesis 7. Nevertheless, the findings indicate that the risk of online shopping does not influence the link between consumer trust and buy intention, with a critical ratio value of 0.517 and estimated value of 0.032 ($p > 0.05$). Thus, H8 unsupported. As a result, the interface quality, the information quality of online review, trust, and enjoyment influence customers' intent to purchase skincare products in an e-marketplace. Also, online review information quality and interface quality can increase consumer trust, while interface quality impacts enjoyment. These findings indicate that incorporating constructs could better explain consumer behavior in terms of purchase intention and comprehensively explain the research model and theory development. The result of each hypothesis shown in Figure 2 below:

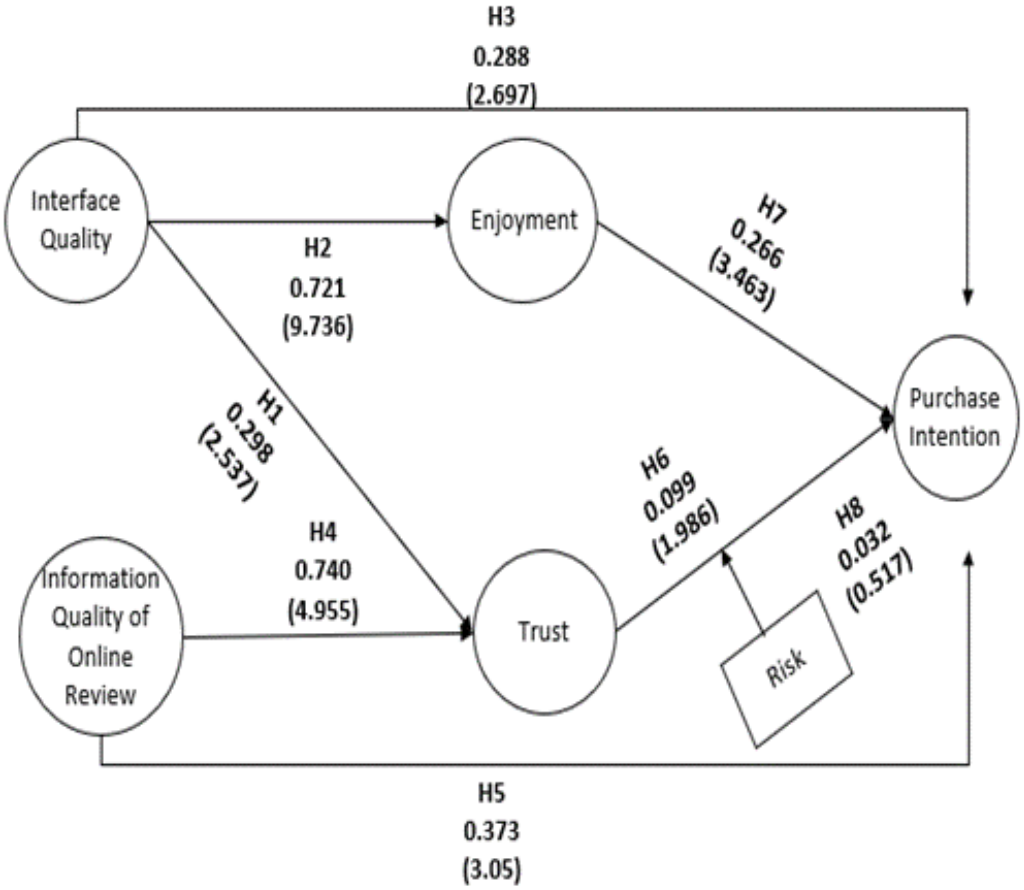

Figure 2: Hypotheses Testing Result

6 CONCLUSIONS

6.1 Conclusions

This study examined the factors that influence customer intent to purchase skincare products in Indonesia's e-marketplace. As distinct descriptive constructs of purchase intention, the study identified interface quality, information quality of online reviews, trust, enjoyment, purchase intention, and risk. Several findings were discovered in this current study. First, based on our review of the literature, this study is the first empirical examination of five constructs and one moderating effect of risk that investigating the determinant factors that influence purchase intentions. Based on the review of the relevant literature, only few of studies have examined the moderating effect of risk [80] [81]. This study revealed that interface quality, information quality of online reviews, trust, and enjoyment have a positive and significant effect on purchase intention. Moreover, risk does not moderate the relationship between trust and intent to purchase. This study suggests that e-marketplaces should place greater reinforcement on developing both quality factors on their platform to promote a positive attitude and behavior of customer (trust, enjoyment, and purchase intention). Furthermore, the identification of interface quality, information quality of online review, trust, and enjoyment as significant contributors to purchase intention suggests that e-marketplace in Indonesia should recognize the importance of these factors to Indonesian customers. The most effective method for companies to attract new customers and retain existing ones is to increase their efforts to maintain a good reputation by providing high-quality interface features and information quality of online review. Therefore, public policymakers and e-marketplace platforms must comprehend this trend and foster more conducive environment to e-marketplace.

6.2 Limitations and Recommendations for Future Study

The study opens up new avenues for academic inquiry. First, additional research can identify more sample size for the future study. The upcoming study could examine a more diverse sample of respondents in order to accurately represent the entire e-marketplace users in Indonesia. This study focused solely on one e-marketplace in Indonesia. Since this study investigated only respondents who purchase Korean skincare products via one e-marketplace, the authors encourage future research to investigate a variety of e-marketplaces with a wide range of products. Future research is

expected to investigate additional e-marketplace environment characteristics that have the potential to act as external stimuli and influence customers' purchasing decisions. Future studies also expected to include mediating variable applied on the current research model. Testable variables include customer satisfaction, customer loyalty, and customer engagement could complement the current research model and give comprehensive explanations regarding with customer behavior in context of e-marketplace.

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REFERENCES

[1] GlobalData, "Indonesian e-commerce market to grow by 23.8% in 2022, forecasts GlobalData," *Global Data*, 2022.
[2] S. Dharma Negara and E. Sri Soesilowati, "E-Commerce in Indonesia: Impressive Growth but Facing Serious Challenges," 2021.
[3] B. Pink and N. Laoli, "Minat belanja online naik, BI optismitis nilai transaksi e-commerce tumbuh 48,4%," *Kontan Indonesia*, Oct. 21, 2021.
[4] M. Elena, "BI Catat Nilai Transaksi E-Commerce Tembus Rp401 Triliun pada 2021," *Bisnis Indonesia*, Jan. 27, 2022.
[5] Janio, "WHAT'S DRIVING INDONESIAN ECOMMERCE GROWTH?," Sep. 2021.
[6] S. S. Nugroho, "Observing the Consumer Behavior of the Indonesian Online Marketplace," *FEB UGM*, 2021. https://feb.ugm.ac.id/en/news/3281-observing-the-consumer-behavior-of-the-indonesian-online-marketplace (accessed Jul. 19, 2021).
[7] Apac, "Indonesia: A Booming Market for Online Shopping," *Apac Outlook*, 2019.
[8] L. Zhu, H. Li, F. K. Wang, W. He, and Z. Tian, "How online reviews affect purchase intention: a new model based on the stimulus-organism-response (S-O-R) framework," *Aslib Journal of Information Management*, vol. 72, no. 4, pp. 463–488, 2020.
[9] V. Patel, K. Das, R. Chatterjee, and Y. Shukla, "Does the interface quality of mobile shopping apps affect purchase intention? An empirical study," *Australasian Marketing Journal*, vol. 28, no. 4, pp. 300–309, 2020.
[10] J. Jacoby, "Stimulus-organism-response reconsidered: An evolutionary step in modeling (consumer) behavior," *Journal of Consumer Psychology*, vol. 12, no. 1, pp. 51–57, 2002.
[11] S. A. Eroglu, K. A. Machleit, and L. M. Davis, "Atmospheric qualities of online retailing," *J Bus Res*, vol. 54, no. 2, pp. 177–184, 2001.
[12] S. Rose, M. Clark, P. Samouel, and N. Hair, "Online Customer Experience in e-Retailing: An empirical model of Antecedents and Outcomes," *Journal of Retailing*, vol. 88, no. 2, pp. 308–322, 2012.
[13] A. Kumar and Y. K. Kim, "The store-as-a-brand strategy: The effect of store environment on customer responses," *Journal of Retailing and Consumer Services*, vol. 21, no. 5, pp. 685–695, 2014.
[14] S. M. C. Loureiro, R. G. Bilro, and A. Japutra, "The effect of consumer-generated media stimuli on emotions and consumer brand engagement," *Journal of Product and Brand Management*, vol. 29, no. 3, pp. 387–408, 2020.
[15] D. Kahneman and A. Tversky, "Prospect Theory: An Analysis of Decision under Risk," *Econometrica*, vol. 47, no. 2, p. 263, Mar. 1979.
[16] S. Burton and L. A. Babin, "Decision-framing helps make the sale," *Journal of Consumer Marketing*, vol. 6, no. 2, p. 15, 1989.
[17] J. Dai and S. Wang, "The Mediating Effect of Perceived Value on Online Reviews' Purchasing Intention–Perspective of Prospect Theory," Jun. 2022.
[18] Y. Wang and B. T. Hazen, "Consumer product knowledge and intention to purchase remanufactured products," *Int J Prod Econ*, vol. 181, pp. 460–469, Nov. 2016.
[19] D. Chen and H. Liang, "Shaping consumer perception to motivate online shopping: A prospect theory perspective," *Special Interest Group on Human-Computer Interaction*, no. May, pp. 60–64, 2006.
[20] T. Bahmanziari and M. D. Odom, "Prospect theory and risky choice in the ecommerce setting: Evidence of a framing effect," *Academy of Accounting and Financial Studies Journal*, vol. 19, no. 1, pp. 85–106, 2015.
[21] S. Huang, "An Empirical Study on the Impact of Customer Purchase Intention Based on Factor Analysis and Structural Equation Model," *Security and Communication Networks*, vol. 2022, 2022.
[22] A. M. Aladwani and P. C. Palvia, "Developing and validating an instrument for measuring user-perceived web quality," *Information and Management*, vol. 39, no. 6, pp. 467–476, 2002.
[23] D. Gefen and D. Straub, "The Relative Importance of Perceived Ease of Use in IS Adoption: A Study of E-Commerce Adoption," *J Assoc Inf Syst*, vol. 1, no. 1, pp. 1–30, 2000.
[24] K. de Wulf, G. Odekerken-Schröder, and D. Iacobucci, "Investments in consumer relationships: A cross-country and cross-industry exploration," *J Mark*, vol. 65, no. 4, pp. 33–50, 2001.
[25] J. W. Moon and Y. G. Kim, "Extending the TAM for a World-Wide-Web context," *Information and Management*, vol. 38, no. 4, pp. 217–230, 2001.
[26] W. B. Dodds, K. B. Monroe, D. Grewal, B. Dodds, and B. Monroe, "Effect of Price, Brand, and Store Information Buyers' Evaluations," *Journal of Marketing Research*, vol. 28, no. 3, pp. 307–319, 1991.
[27] S. Kamalul-Ariffin, T. Mohan, and Y. N. Goh, "Influence of consumers' perceived risk on consumers' online purchase intention," *Journal of Research in Interactive Marketing*, vol. 12, no. 3, pp. 309–327, 2018.
[28] U. Bhandari, T. Neben, K. Chang, and W. Y. Chua, "Effects of interface design factors on affective responses and quality evaluations in mobile applications," *Comput Human Behav*, vol. 72, pp. 525–534, 2017.
[29] I. Erkan and C. Evans, "The influence of eWOM in social media on consumers' purchase intentions: An extended approach to information adoption," *Comput Human Behav*, vol. 61, pp. 47–55, Aug. 2016.
[30] M. J. Thomas, B. W. Wirtz, and J. C. Weyerer, "Determinants of online review credibility and its impact on consumers' purchase intention," *Journal of Electronic Commerce Research*, vol. 20, no. 1, pp. 1–20, 2019.
[31] G. Cui, H. K. Lui, and X. Guo, "The effect of online consumer reviews on new product sales," *International Journal of Electronic Commerce*, vol. 17, no. 1, pp. 39–58, 2012.
[32] G. C. Bruner and A. Kumar, "Explaining consumer acceptance of handheld Internet devices," *J Bus Res*, vol. 58, no. 5, pp. 553–558, 2005.
[33] M. Cheung, C. Luo, C. Sia, and H. Chen, "Credibility of electronic word-of-mouth: Informational and normative determinants of on-line consumer recommendations," *International Journal of Electronic Commerce*, vol. 13, no. 4, pp. 9–38, 2009.
[34] Y.-H. Fang, "Beyond the Credibility of Electronic Word of Mouth: Exploring eWOM Adoption on Social Networking Sites from Affective and Curiosity Perspectives," *International Journal of Electronic Commerce*, vol. 18, no. 3, pp. 67–102, Apr. 2014.
[35] T. Pipitwanichakarn and N. Wongtada, "Leveraging the technology acceptance model for mobile commerce adoption under distinct stages of adoption: A case of micro businesses," *Asia Pacific Journal of Marketing and Logistics*, vol. 33, no. 6, pp. 1415–1436, 2019.
[36] H. H. Chang and S. W. Chen, "Consumer perception of interface quality, security, and loyalty in electronic commerce," *Information and Management*, vol. 46, no. 7, pp. 411–417, 2009.
[37] K. Hassanein and M. Head, "Manipulating perceived social presence through the web interface and its impact on attitude towards online shopping," *International Journal of Human Computer Studies*, vol. 65, no. 8, pp. 689–708, 2007.
[38] P. W. Handayani, I. M. E. Ariantana, and A. A. Pinem, "How To Increase Customer Repurchase Intention in An Online Retailing Store? An Extended Expectation Confirmatory Model," *International Journal of Electronic Commerce Studies*, vol. 10, no. 1, pp. 1–21, 2019.
[39] N. Pappas, "Marketing strategies, perceived risks, and consumer trust in online buying behaviour," *Journal of Retailing and Consumer Services*, vol. 29, pp. 92–103, 2016.
[40] J. M. Pearson, A. Pearson, and D. Green, "Determining the importance of key criteria in web usability," *Management Research News*, vol. 30, no. 11, pp. 816–828, Oct. 2007.
[41] M. Tarafdar and J. ("Jennifer") Zhang, "Analyzing the Influence of Web Site Design Parameters on Web Site Usability," *Information Resources Management Journal*, vol. 18, no. 4, pp. 62–80, Oct. 2005.
[42] C. P. Brazil *et al.*, "The Effect of Online Wet Markets Website Quality on the Purchase Intention of Consumers in Caloocan City," 2022.
[43] D. V. Mustika and L. Wahyudi, "Does the Quality of Beauty E-commerce Impact Online Purchase Intention? The Role of Perceived Enjoyment and Perceived Trust," *International Journal of Economics, Business and Management Research*, vol. 06, no. 04, pp. 199–218, 2022.
[44] J. H. Choi and H.-J. Lee, "Facets of simplicity for the smartphone interface: A structural model," *Int J Hum Comput Stud*, vol. 70, no. 2, pp. 129–142, Feb. 2012.
[45] N. E. R. Wuryandari, P. Vincentiar, and D. Permana, "Buying Intention through User Interface Design," *European Research Studies Journal*, vol. XXII, no. Issue 3, pp. 470–479, 2019.
[46] U. Bhandari, T. Neben, and K. Chang, "Understanding visual appeal and quality perceptions of mobile apps: An emotional perspective," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 9169, pp. 451–459, 2015.
[47] B. Ganguly, S. B. Dash, D. Cyr, and M. Head, "The effects of website design on purchase intention in online shopping: the mediating role of trust and the moderating role of culture," *International Journal of Electronic Business*, vol. 8, no. 4/5, p. 302, 2010.
[48] Y. Lee, "Impacts of sociability on perceived information quality of customer reviews for online shopping sites," *International Journal of Contents*, vol. 14, no.

2, pp. 16–23, 2018.

[49] A. Elwalda and I. Erkan, "Your comments are important to me! The impacts of online customer reviews in shopping websites," *International Journal of Internet Marketing and Advertising*, vol. 12, no. 1, p. 1, 2018.

[50] X. Chen, Q. Huang, R. M. Davison, and Z. Hua, "What Drives Trust Transfer? the Moderating Roles of Seller-Specific and General Institutional Mechanisms," *International Journal of Electronic Commerce*, vol. 20, no. 2, pp. 261–289, 2015.

[51] K. Zhao, A. C. Stylianou, and Y. Zheng, "Sources and impacts of social influence from online anonymous user reviews," *Information and Management*, vol. 55, no. 1, pp. 16–30, 2018.

[52] R. Filieri, "What makes online reviews helpful? A diagnosticity-adoption framework to explain informational and normative influences in e-WOM," *J Bus Res*, vol. 68, no. 6, pp. 1261–1270, 2015.

[53] F. Zhu and X. Zhang, "Impact of online consumer reviews on Sales: The moderating role of product and consumer characteristics," *J Mark*, vol. 74, no. 2, pp. 133–148, 2010.

[54] R. Obiedat, "Impact of Online Consumer Reviews on Buying Intention of Consumers in UK: Need for Cognition as the Moderating Role," *International Journal of Advanced Corporate Learning (iJAC)*, vol. 6, no. 2, p. 16, Jul. 2013.

[55] E. Bonsón Ponte, E. Carvajal-Trujillo, and T. Escobar-Rodríguez, "Influence of trust and perceived value on the intention to purchase travel online: Integrating the effects of assurance on trust antecedents," *Tour Manag*, vol. 47, pp. 286–302, 2015.

[56] S. Grabner-Kräuter and S. Bitter, "Trust in online social networks: A multifaceted perspective," *Forum for Social Economics*, vol. 44, no. 1, pp. 48–68, 2014.

[57] P. Punyatoya, "Effects of cognitive and affective trust on online customer behavior," *Marketing Intelligence and Planning*, vol. 37, no. 1, pp. 80–96, 2019.

[58] H. Marriott and M. Williams, "Exploring consumers perceived risk and trust for mobile shopping: A theoretical framework and empirical study," *Journal of Retailing and Consumer Services*, vol. 42, no. December 2017, pp. 133–146, 2018.

[59] D. Kim, "An investigation of the effect of online consumer trust on expectation, satisfaction, and post-expectation," *Information Systems and e-Business Management*, vol. 10, no. 2, pp. 219–240, 2012.

[60] S. S. Bedi, S. Kaur, and A. K. Lal, "Understanding Web Experience and Perceived Web Enjoyment as Antecedents of Online Purchase Intention," *Global Business Review*, vol. 18, no. 2, pp. 465–477, 2017.

[61] A. Elwalda, K. Lü, and M. Ali, "Perceived derived attributes of online customer reviews," *Comput Human Behav*, vol. 56, pp. 306–319, 2016.

[62] D. S. Kumar, K. Purani, and S. A. Viswanathan, "Influences of 'appscape' on mobile app adoption and m-loyalty," *Journal of Retailing and Consumer Services*, vol. 45, no. August, pp. 132–141, 2018.

[63] M. Gong, M. Xu, A. Luqman, L. Yu, and A. Masood, "Understanding the role of individual differences in mobile SNS addiction," *Kybernetes*, vol. 49, no. 12, pp. 3069–3097, Jan. 2020.

[64] M. Scardamalia and C. Bereiter, "Smart technology for self-organizing processes," Smart Learning *Environments*, vol. 1, no. 1, pp. 1–13, 2014.

[65] K. Akdim, L. v. Casaló, and C. Flavián, "The role of utilitarian and hedonic aspects in the continuance intention to use social mobile apps," *Journal of Retailing and Consumer Services*, vol. 66, p. 102888, May 2022.

[66] M. H. al Khasawneh and N. Haddad, "Analysis of the effects of ease of use, enjoyment, perceived risk on perceived value and subsequent satisfaction created in the context of C2C online exchanges," *International Journal of Electronic Marketing and Retailing*, vol. 11, no. 3, pp. 217–238, 2020.

[67] T. K. Huang, "Exploring the antecedents of screenshot-based interactions in the context of advanced computer software learning," *Comput Educ*, vol. 80, pp. 95–107, 2015.

[68] J. Yoo and M. Kim, "Online product presentation: The effect of product coordination and a model's face," *Journal of Research in Interactive Marketing*, vol. 6, no. 1, pp. 59–72, 2012.

[69] I. L. Wu, M. L. Chiu, and K. W. Chen, "Defining the determinants of online impulse buying through a shopping process of integrating perceived risk, expectation-confirmation model, and flow theory issues," *Int J Inf Manage*, vol. 52, no. May 2019, p. 102099, 2020.

[70] M. Zendehdel, L. H. Paim, and S. B. Osman, "Students' online purchasing behavior in Malaysia: Understanding online shopping attitude," *Cogent Business & Management*, vol. 2, no. 1, p. 1078428, Dec. 2015.

[71] S. Rahmi, G. B. Ilyas, H. Tamsah, and A. R. Munir, "Perceived risk and its role in the influence of brand awareness on purchase intention: study of Shopee users," *Jurnal Siasat Bisnis*, vol. 26, no. 1, pp. 97–109, Jan. 2022.

[72] G. Lăzăroiu, O. Neguriţă, I. Grecu, G. Grecu, and P. C. Mitran, "Consumers' Decision-Making Process on Social Commerce Platforms: Online Trust, Perceived Risk, and Purchase Intentions," *Front Psychol*, vol. 11, May 2020.

[73] J. C. Soares, R. Limongi, J. H. de Sousa Júnior, W. S. Santos, M. Raasch, and L. Hoeckesfeld, "Assessing the effects of COVID-19-related risk on online shopping behavior," *Journal of Marketing Analytics*, Feb. 2022.

[74] H. W. Kim, H. C. Chan, and S. Gupta, "Value-based Adoption of Mobile Internet: An empirical investigation," *Decis Support Syst*, vol. 43, no. 1, pp. 111–126, 2007.

[75] Y. S. Wang, C. H. Yeh, and Y. W. Liao, "What drives purchase intention in the context of online content services? the moderating role of ethical self-efficacy for online piracy," *Int J Inf Manage*, vol. 33, no. 1, pp. 199–208, 2013.

[76] M. H. Hsu, L. W. Chuang, and C. S. Hsu, "Understanding online shopping intention: The roles of four types of trust and their antecedents," *Internet Research*, vol. 24, no. 3, pp. 332–352, 2014.

[77] H. Zhang, Y. Lu, S. Gupta, and L. Zhao, "What motivates customers to participate in social commerce? the impact of technological environments and virtual customer experiences," *Information and Management*, vol. 51, no. 8, pp. 1017–1030, 2014.

[78] C. Nam, K. Cho, and Y. do Kim, "Cross-cultural examination of apparel online purchase intention: S-O-R paradigm," *Journal of Global Fashion Marketing*, vol. 12, no. 1, pp. 62–76, 2021.

[79] J. F. Hair, B. J. Babin, R. E. Anderson, and W. C. Black, *Multivariate Data Analysis.pdf*. Harlow, Essex: Pearson Education Limited, 2010.

[80] A. Bhatti, S. Saad, and S. M. Gbadebo, "Moderator trust, subjective norms influence risk and online shopping behavior of consumers," *International Journal of Scientific and Technology Research*, vol. 9, no. 1, pp. 627–641, 2020.

[81] S. A. Qalati, E. G. Vela, W. Li, S. A. Dakhan, T. T. Hong Thuy, and S. H. Merani, "Effects of perceived service quality, website quality, and reputation on purchase intention: The mediating and moderating roles of trust and perceived risk in online shopping," *Cogent Business and Management*, vol. 8, no. 1, 2021.

Understanding the Trend of Scientific Productivity Analysis

Literature Review of Relevant Papers

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ABSTRACT

The productivity of academic scientific world is an important indicator for the allocation of university research funds. In order to understand the current state of research on dissertation productivity, this study organizes 21 papers on dissertation productivity published between 1986 to 2021 and compiles tables to understand research on dissertation productivity and discuss related items. The results obtained from the summary table show that case studies of papers tend to focus on one-unit influencing factors, and the analytical perspective is not comprehensive. Many papers make database decisions based on the authoritative nature of the database. It becomes clear that the method of analyzing productivity in the papers is overwhelmingly a statistical mathematical analysis. When a government or organization wants to evaluate scientific productivity, it should not focus on efficiency, but should choose the appropriate scientific productivity evaluation indicators according to the needs. The ease of data acquisition suggests that country-level scientific productivity is more suitable for qualitative analysis, while organization-level or individual-level factors are suitable for quantitative analysis studies.

CCS CONCEPTS

• **General and reference** → Document types; Surveys and overviews.

KEYWORDS

Scientific productivity, Productivity indicator, Literature review

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1 INTRODUCTION

Scientific productivity is defined as maximizing the results by making full use of limited human and financial resources for research and development of science and technology. Attention to this indicator is beginning to have real meaning for two reasons: First, countries are facing the problem of limited research funding, and they are forced to rely on the university's scientific productivity to allocate research resources. For example, in the fiscal 2019 budget, the Japanese government distinguished the amount allocated to national universities according to the research results, assuming that it reflected the analysis of the Ministry of Finance, which hastened reforms under the policy of "selection and concentration". Second, economic growth comes from people generating ideas. As shown in Figure 1, although the number of papers in the major countries all show an increasing trend, the growth rate of papers is clearly different. In ordering to acquire an international competitive edge in science and technology, universities need to improve the quality of their knowledge production, strengthen their international competitive attitude in science and technology.

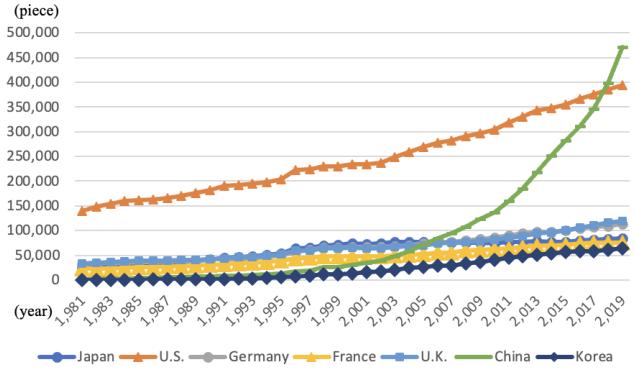

Figure 1: Changes in the number of papers in major countries (all fields, integer counting method)

2 METHODOLOGY

This paper is divided into three steps for the study, firstly, searching literature, secondly, reviewing papers and extracting the attribute of reviewed papers, and finally, discussing the trend of scientific productivity analysis.

2.1 Searching Literature (Step 1)

Using Google Scholar, a search was conducted using the keywords "scientific productivity" and "thesis productivity" 21 studies from 1981 to 2021 were selected.

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Table 1: Profile of reviewed papers

NO	Era	Author	Title
1	1986	A. VAN HEERINGEN	The relationships between age, mobility and scientific productivity.
2	2006	FRANZ BARJAK	Research productivity in the internet era
3	2007	Bart Van Looy	Developing technology in the vicinity of science: An examination of the relationship between science intensity and technological productivity within the field of biotechnology
4	2008	LINEY MANJARRÉS-HENRÍQUEZ	Coexistence of university–industry relations and academic research: Barrier to or incentive for scientific productivity
5	2011	Ozlem Inanc Onur Tuncer	The effect of academic inbreeding on scientific effectiveness
6	2011	Yuko Ito	Research activities of university faculty members characterized by paper productivity
7	2012	Ernesto R. Gantman	Economic, linguistic, and political factors in the scientific productivity of countries
8	2014	Giovanni Abramo Ciriaco Andrea DAngelo	How do you define and measure research productivity?
9	2014	Zhigang Hu	How are collaboration and productivity correlated at various career stages of scientists
10	2014	Gholizadeh, Hossein	Relationship among economic growth, internet usage and publication productivity:
11	2014	Radhamany Sooryamoorthy	Publication productivity and collaboration of researchers in South Africa: new empirical evidence
12	2015	Svein Kyvik and Dag W. Aksnes	Explaining the increase in publication productivity among academic staff: a generational perspective
13	2017	Shuhei Aoki	Allocation of research resources and publication productivity in Japan: a growth accounting approach
14	2018	Masanuki Ijin	Considering productivity analysis of papers: what analysts and users should check and issues in conducting the analysis.
15	2019	Nicole Verrier Crain W. Mark Crain	Determinants of publication productivity: an empirical analysis
16	2020	Yoke Dellenback	A look at research productivity: examining the relationships between publications, citations, and research and development expenditures
17	2020	Gennady V. Osipov	factors in managing publication productivity in Russian universities
18	2021	Mohan Pyari Maharjan	Research productivity of self-initiated expatriate academics: Influences of job demands, resources and cross-cultural adjustment
19	2021	B. Elango, Dong-Geun,Oh,P. Rajendran	Assessment of scientific productivity by India and South Korea
20	2021	Prashasti Singh, Vivek Kumar Singh, Parveen Arora	India's rank and global share in scientific research: how data sourced from different databases can produce varying outcomes?
21	2021	Vivek Kumar Singh, Parveen Arora	India's rank and global share in scientific research: how publication counting method and subject selection can vary the outcomes?

2.2 Reviewing Papers and Extracting the Attribute of Reviewed Papers (Step 2)

The 12 items extracted from the literature were time, author, title, purpose, unit of analysis, source of data acquisition, time of data acquisition, productive index, description of the main factors, method of analysis and results.

2.3 Discussing the Trend of Scientific Productivity Analysis (Step 3)

Conduct an inductive analysis based on the paper discussion form and the factor discussion form.

3 REVIEWED PAPER OUTLINE (STEP 1)

The 21 papers are arranged in chronological order as shown in Table 1.

4 ATTRIBUTE OF SCIENTIFIC PRODUCTIVITY ANALYSIS (STEP 2)

There are two main types of papers on scientific productivity. The first type is theoretical research that analyzes the relationship between the productivity of a paper and the relationship between one or more influencers, analyzes papers on calculation methods as well as evaluation indicators of scientific productivity. The second type is a case study that analyzes the main factors of changes in scientific

Table 2: Attribute of reviewed papers I

NO.	Purpose	Analytical unit
1	Relationship between age and productivity	Individual
2	Relationship between internet application use and research productivity	Individual
3	Relationship between scientific intensity and technical productivity	Country
4	Coexistence of industry-academia collaboration and academic research	Individual
5	Examine the impact of in-bleed on scientific validity through case studies	Individual
6	Relationship between paper productivity and research environment, etc.	Individual
7	operationalize the concept of productivity in the specific context of a research activity and to propose a measurable form of productivity.	Country
8	operationalize the concept of productivity in the specific context of a research activity and to propose a measurable form of productivity.	Organization
9	Impact of collaboration on researcher productivity	Individual
10	Relationship between publications, gross domestic product (GDP), and internet usage	Country; Organization
11	Examine the interrelationships between dissertation productivity and collaborative research, as well as the differences between sectors of higher education and research institutions	Organization; Individual
12	Norwegian research universities have experienced a large individual increase in the publication of scientific and scholarly papers over the past 30 years. The purpose of this article is to explain the reasons for this growth, generation by generation.	Individual
13	What factors contributed to the stagnation of the number of papers in Japan in the 2000s; how did the increased emphasis on research funding affect the number of papers in Japan?	Organization
14	Points to consider when analyzing productivity and interpreting analysis results	Country
15	Estimating the determinants of publication productivity using data from Robert D. Tollison (RDT)	Individual
16	Examine institutional-level research productivity by examining R&D expenditures and article outputs; Examine faculty-level research productivity by examining faculty article production, article citations, and R&D expenditures	Organization
17	Identifying the main management factors leading to a significant increase in publication productivity in Russian universities	Country
18	Analyzing the dynamics of academic achievement in a cross-cultural environment	Individual
19	Quantitative analysis is to compare the scientific productivity of Indian and Korean countries	Country
20	Attempting to analyze the endogenous factors of the variation seen in India's global research results, rankings, and ratios	Country
21	This paper seeks to determine the impact of exogenous factors, primarily publication counting methods and subject selection, on the outcome of research evaluations.	Country

productivity of a subject and proposes solutions for improvement together.

Out of the 21 previous studies, three papers have evaluated academic productivity measurement methods and mainstream academic productivity measurement methods. Abramov •Andre (2014) proposed a Measureal Scientific Strength, an indicator that includes both the quantity and quality of productivity and can be measured at different organizational levels. In Igami (2018), we presented that the analysis of scientific productivity changes depending on the counting method of the paper and the selection of calculation items. There were 12 studies on the influencing factors of scientific productivity, such as age [1], Internet utilization rate [2], industry-academia collaboration [4], joint research [9], etc. In addition, there are six papers that analyze the current state of scientific production of the research subjects and explore the main factors affecting them.

If the analytical units of previous research are arranged in chronological order, it can be seen that they have changed from an individual-level object to an organization and country level object. This change is likely to be due to the view that factors of the country and organization (such as the allocation policy) have a greater impact on the productivity of the researchers' papers than on individual-level factors (age, gender, etc.). The specific projects are shown in Table 2.

Objective and accurate research data should be the basis of valid research results and should be as accurate as conditions allow. As for the source of data, 30% of the papers adopting the data acquisition method by questionnaire are the subjects of the research by the questionnaire at the individual level. The reason is that most of the data types at the individual level are more private (age, learning time, etc.), and it is difficult to obtain data published on the Internet. The advantage of the questionnaire method is that it is easy and quick to obtain data, and the disadvantage is that the data is somewhat subjective and it is difficult to guarantee the reliability of the data. Instead of surveys, you can get data from information

Table 3: Attribute of reviewed papers II

NO.	Data Source	Data period	Productivity Indicators
1	Survey	2001	Number of papers; number of citations in scientific literature
2	Survey	2001-2002	Number of papers
3	USPTO	1992-1999	Number of papers; Number of patents per capita
4	Institute for Scientific Information	2003–2004	Number of papers
5	Web of Science, ARBİS	/	H index
6	Survey Report on Full-Time Equivalent Data for Universities and Other Institutions (2008 Survey)	/	Number of papers
7	SCOPUS	2009	Number of papers
8	QS World University Rankings	2006-2010	Scientific Strength Score; Number of papers
9	Web of Science	1981-2010	Number of papers by first author; Number of authors; Number of papers
10	Scopus database	1996-2011	Number of papers; number of citations in scientific literature
11	Survey	2007-2008	Number of papers; Number of authors
12	Survey (1982,1992,2001), Cristin (2005–2013)	1982-12013	equivalence value
13	NISTEP	2005-2009	Number of papers
14	Institute for Science, Technology, and Policy Studies Research Document-262 (2017)	1981-2016	Number of papers
15	Institute for Scientific Information	1968-2006	Number of pages; Number of papers
16	the National Science Foundation's Higher Education Research and Development Survey;Web of Science	2018	Number of papers
17	Web of Science	1986-2018	Number of papers; number of citations in scientific literature
18	Survey		Number of papers; Number of authors
19	SCOPUS	1998–2018	Relative citation impact; Relative growth index; Activity index; Compound annual growth rate; Number of papers
20	Web of Science, Scopus, Dimensions	2010-2019	Compound annual growth rate; number of papers
21	(a) NSF Science and Engineering Indicators Report, 2020 (b) DST-Elsevier commissioned study report 2019 (c) Scopus database.	2016	Number of papers

and statistics sites such as the Web of science, institute for scientific information, and official national reports. In this way, the method of obtaining data using statistical information sites has the advantage of ensuring the reliability of the data, but the disadvantage is that there is a lot of work and it takes time to collect data.

We found that Individual-level data typically has a smaller time span, while country and organization-level data has a large time span. there are several reasons for this situation, but one is that due to the limitations of human memory, the validity of the data is guaranteed only over a smaller time span, and the second is that country and organizational statistics take a long time to perform statistical work by specialized staff, so the validity of the data is guaranteed. In addition, short-term data from countries and organizations has a relatively long time span because there is no sense of regularly analyzing them together.

When evaluating the productivity of a researcher's paper, the number of papers has attracted attention as an important evaluation index. In recent years, the number of highly productive evaluation indicators has been increasing gradually, and indicators such as the number of citations and pages have been included. This is because the number of papers is evaluated as the amount of output of researchers, and if you try to evaluate the quality of the paper at the same time, you need to introduce a new evaluation index (e.g., h-index) to evaluate productivity. The specific projects are shown in Table 3.

Of the papers for researchers, there were relatively large sample-sized papers involving up to 7,000 researchers. In papers that study organs, the number of samples is concentrated in the range of 10 to 30 and 60 to 80, respectively. The sample sizes of papers for countries were all within the range of 20. The reason for this is that individual-level research is special and requires a large amount of

data to base general conclusions, while institutional and country-level research requires more data, so the sample size needs to be less large.

The data types are more varied at the individual level of research and less varied at the country or organizational level. We believe that this result is due to the fact that individuals, as the main actors in conducting research, need all types of data that reflect the background and characteristics of the study, and that multiple types of data can increase the reliability of the analysis.

While statistical analysis is used to analyze paper productivity, researchers are also trying to analyze the main causes that affect productivity side-by-side using research methods in other fields (such as growth accounting). When applying statistics to productivity analysis, other fielding methods are a good analysis method when the sample source is limited, since the size of the sample has a significant impact on the results of the statistical analysis. The disadvantages of other fields, when analyzing productivity, it is necessary to prove the feasibility of the analysis principle by verification, which increases the difficulty of interpreting the results. The specific projects are shown in Table **??**.

5 DISCUSSION

The literature is divided into two themes based on the content of the literature, which focuses on theoretical studies related to dissertation productivity, i.e., the evaluation indicators of dissertation productivity and the factors that influence dissertation productivity. This section discusses the advantages and disadvantages of evaluating indicators of dissertation productivity and summarizes the influence of various factors on dissertation productivity from three perspectives: country, organizational, and individual.

5.1 Analysis of the Strengths and Weaknesses of Scientific Productivity Indicators

The indicators of dissertation productivity can be divided into three types: indicators for evaluating the number of dissertations, such as the number of dissertations, the number of dissertation pages, the number of first-author papers, the number of authors. The second type of indicators is the evaluation of the quality of papers, such as the evaluation of scientific intensity, the number of papers cited, the number of patents, equal value, and the relative citation impact. The third category of indicators is the one that can evaluate both the quantity and quality of papers, such as H-index, relative growth index. Quantitative indicators, represented by the number of papers, are often used for international comparisons of paper production, and are heavily used mainly because of their easy accessibility and use. The number of cited papers, on the other hand, is widely used to evaluate the quality of papers, using the number of commonly used papers together as an evaluation index. However, it is worth noting that for disciplines such as natural sciences where the output of a paper is the final result, the number of papers and the number of papers cited can be used as evaluation indicators from already extent, while the number of papers and the number of papers cited do not really reflect the productivity of humanities where the composition of research results is complex. Scientists have been hoping to create a new indicator to evaluate both quantity and quality of papers, but in fact there does not seem to be a perfect indicator so far,

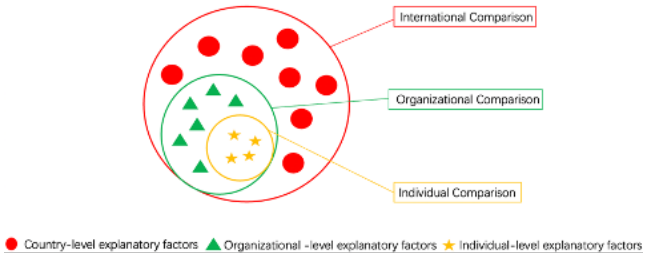

Figure 2: The relationship between the comparative of scientific productivity and the main causes

such as the most famous of the composite indicators, the H-index, which does not evaluate the impact of papers below the number of citations. As Giovanni Abramo says, while bibliometricians undoubtedly intended to provide useful indicators and ever more accurate and reliable methods, they have actually been the cause of increasing confusion. In Benedetto Torrisi's paper, he classifies scientific research results it is divided into scientific productivity of the first type (scientific publications); scientific productivity of the second type (awards and academic positions); productivity in terms of external relationships (or external advice); and educational productivity. Evaluating a paper text as a researcher's scientific results may not fully indicate the researcher's full scientific research results, but it seems that a simple evaluation indicator is a more cost-effective option in terms of matters such as state allocation of research funds. In addition, different evaluation indicators should be chosen for the evaluation of the productivity of the dissertation between different disciplines, and productivity evaluation between different disciplines is of no practical importance.

5.2 Multi-angle Description of the Main Cause Summary

Based on the data source of the explanatory factors, the explanatory factors were classified into country-level, organization-level, and individual-level. In terms of frequency of use, individual-level factors are frequently used, followed by organization-level factors, and the least frequently used are country-level factors. There are two possible reasons for this phenomenon: first, country-level factors are more difficult to obtain and less accurate, so they are not often used, while individual-level factors are relatively easy and accurate to obtain; second, the main body of scientific production is the individual, and although country-level factors and organizational-level factors have indirect effects on individual scientific production, the impact of individual-level factors is more direct and more relevant. The impact of individual-level factors is more direct and relevant. The relationship between the different levels of scientific productivity and the description of the essential factors is shown in Figure 2. In the specific use of each level of factors, country-level scientific productivity comparisons usually include three levels of explanatory factors, organizational-level scientific productivity comparisons are for organizational-level and individual-level factors, and individual-level scientific productivity comparisons usually use only individual-level explanatory factors.

Table 4: Attribute of reviewed papers III

NO.	Explanatory factor	Method	Result
1	Research time; Research type; Age; Position	multivariate regression analysis	It indicates a slowdown in the rate of productivity growth after age 30.
2	Age; Position; Affiliation; Joint Research	negative binomial hurdle model	There is a positive relationship between Internet use and research productivity.
3	Number of Permits	multivariate regression analysis	Technical productivity is positively related to scientific intensity.
4	Age; Position; Gender; Industry & Learning	Average value comparison method	The UIR will have a positive impact on the productivity of a paper only if it is developed under an R&D contract and the funds received do not exceed 15% of the researcher's total budget.
5	Position	negative binomial regression model	Academic imbibers show a negative impact on scientific productivity and effectiveness. On average, non-inbreeders have a 35% higher h-index than inbreeders. The average career of inbred faculty is about 5 years longer than that of non-inbred faculty.
6	Research hours; Age; Position; Gender; Specialty; Number of publications of research activities; Number of patents; Research funds; Organization	odds ratio	Age, organizational affiliation, research funding, and number of patents are variables strongly related to productivity. Social service activity hours" is a factor strongly related to the decrease in research hours.
7	GDP; GDP per capita	negative binomial regression model	Political aspects are important determinants of scientific results, but they are limited to certain disciplines, such as the social sciences. Economic factors are related to scientific research output, a factor common to the productivity of all fields of study. The theory of linguistic imperialism does not seem to have the power to predict scientific productivity in some fields.
8	Research time	Quantitative analysis	We proposed a proxy measure of productivity, FSS, which includes both quantity and quality of production and can be measured at different organizational levels.
9	GDP per capita	Statistical Analysis	In the early stages of their careers, there is a strong negative correlation between COPP and productivity and a weak positive correlation between COPS and productivity. From mid-career onward, the correlation between collaboration and productivity becomes stronger.
10	GDP; GDP per capita	nonparametric test	There is a positive and significant relationship between GDP and the number of papers; There is a positive and significant relationship between the number of people with access to the Internet and the number of papers.
11	Age; Position; Gender; Specialty; Organization	multivariate regression analysis	Relationship between collaboration and productivity varies by type of collaboration; respondents affiliated with research institutions engage in more research projects, lead more projects, and participate in fewer collaborative projects compared to academics
12	Research time	Quantitative analysis	The increase in qualified academic staff and research collaborators, improved research conditions, and the introduction of incentive and reward systems must be considered as partially explaining the increase in productivity.
13	Research time; Research funding; Personnel costs	growth accounting	Shortening of research hours is the main cause of the decline in the number of papers; the increased emphasis on research funding has had the effect of improving distortions in the allocation of research resources and boosting the number of papers in Japan.
14	Research funding	Integer Counting vs. Fraction Counting	The results of the analysis of paper productivity depend on the choice of denominator and numerator.
15	Age; Expertise; Research Funding; Organization; Industry-University Collaboration	multivariate regression analysis	Robert Tollison's publications appear to be influenced by collaborations, diversification of research portfolios, industry-university partnerships, and research funding. Robert Tollison's production patterns are also influenced by interests outside of work and affiliation with specific institutions.

16	Research Funding; Number of Researchers; Organization	regression analysis	There is a significant relationship between R&D expenditures and publications at the institutional level, and between R&D expenditures, publications, and citations at the faculty level.
17	Age; Position; Number of publications of research activities	Principal Component Method	For younger faculty members, the main factors affecting publication productivity are scientific and pedagogical potential, communication skills and international activities, professional development prospects, and psychological satisfaction. For older faculty members, economic aspects are particularly important.
18	Age; Position; Gender; Specialty; Organization	Retirement analysis	The higher the level of cross-cultural adaptation, the stronger the relationship between the number of doctoral students supervised and research productivity
19	GDP; GDP per capita	Quantitative analysis	Between 1998 and 2018, India improved its global standing by eight and South Korea by three. Compared to India, Korea has a higher percentage of international co-publications. In several fields, such as chemical engineering and materials science, both countries maintain excellent positions.
20	GDP per capita	Quantitative analysis	Variations in the volume, global share, and ranking of research outputs in the data of the various databases are observed even in the most productive countries. For research outputs in specific fields, all of these databases show widely differing evidence.
21	GDP; GDP per capita	Quantitative analysi3s	Countries with higher joint research outputs will have greater losses when using the fractional calculation method. Conversely, countries with low joint research outputs will improve their rankings when fractional computation is used. The relative research performance ranks of countries vary widely from field to field.

6 CONCLUSION REMARKS

A literature review was conducted by way of creating a table of articles on article productivity. From the results of the analysis, the case studies of previous studies tend to focus on single-level influencing factors, and the analytical perspective is not comprehensive. Many prior studies determined databases based on their authoritative nature. Although the method of analyzing productivity in prior studies is overwhelmingly a statistical mathematical analysis, productivity as an economic concept is better analyzed from an econometric perspective.

The number of papers is the most commonly used index for evaluating the productivity of papers, and it is usually used together with the citation rate of papers in the process. The composite evaluation index has the advantage of high efficiency, but at the same time there are certain evaluation blind spots. When a government or organization wants to evaluate scientific productivity, it should not focus on efficiency, but should choose the appropriate scientific productivity evaluation index according to the needs. The relationship between the level of scientific productivity comparison and the stated factors suggests that country-level scientific productivity comparisons should not be limited to country-level factors but should also include organizational and individual-level factors. The ease of data acquisition suggests that country-level scientific productivity is more suitable for qualitative analysis, while organization-level or individual-level factors are suitable for quantitative analysis studies.

REFERENCES

[1] Van Heeringen A and Dijkwel P, 1987."The relationships between age, mobility and scientific productivity. Part II: Effect of age on productivity.", *Scientometrics*, Vol,11(5-6) pp. 281-293.

[2] Barjak F. 2006. "Research productivity in the internet era.", *Scientometrics*, Vol, 68(3), pp. 343-360.

[3] Van Looy, B., Magerman, T., & Debackere, K. 2007. "Developing technology in the vicinity of science: An examination of the relationship between science intensity (of patents) and technological productivity within the field of biotechnology.", *Scientometrics*, Vol,70(2), pp.441-458.

[4] Manjarrés-Henríquez, L., Gutiérrez-Gracia, A., & Vega-Jurado, J. 2008. "Coexistence of university-industry relations and academic research: Barrier to or incentive for scientific productivity." *Scientometrics*, Vol,76(3), pp.561-576.

[5] Inanc, O., & Tuncer, O. 2011. "The effect of academic inbreeding on scientific effectiveness.", *Scientometrics*, Vol,88(3), pp.885-898.

[6] Yuko Ito. 2012. "Research Activities of University Faculty Members Characterized by Paper Productivity.", *Research Technology Planning*, Vol,26(1-2), pp.73-84.

[7] Gantman, E. R. 2012. "Economic, linguistic, and political factors in the scientific productivity of countries.", *Scientometrics*, Vol,93(3), pp.967-985.

[8] Abramo, G., & D'Angelo, C. A. 2014. "How do you define and measure research productivity?", *Scientometrics*, Vol,101(2), pp. 1129-1144.

[9] Hu, Z., Chen, C., & Liu, Z. 2014. "How are collaboration and productivity correlated at various career stages of scientists?". *Scientometrics*, Vol, 101(2), pp. 1553-1564.

[10] Gholizadeh, H., Salehi, H., Embi, M. A., Danaee, M., Motahar, S. M., Ale Ebrahim, N., ... & Abu Osman, N. A. 2014. "Relationship among economic growth, internet usage and publication productivity: comparison among ASEAN and world's best countries." *Modern Applied Science*, Vol, 8(2), pp. 160-170.

[11] Mduduzi Nkosinathi Gladwin Mtshali, Radhamany Sooryamoorthy. 2019. Publication productivity and collaboration of researchers in South Africa: new empirical evidence. *Futures*, Vol 111, 194-204.

[12] Kyvik, S., & Aksnes, D. W. 2015. "Explaining the increase in publication productivity among academic staff: A generational perspective." *Studies in Higher Education*, Vol, 40(8), pp. 1438-1453.

[13] Aoki, Shuhei, and Megumi Kimura. 2017. "Allocation of Research Resources and Publication Productivity in Japan: A Growth Accounting Approach." Ministry of Finance, Japan, *Public Policy Review*, Vol.13, No.3.

[14] Masanuki Ijin. 2018. "Considering productivity analysis of papers: what analysts and users should check and issues in conducting the analysis." *STI Horizon: Opening New Horizons of Innovation*, Vol, 4(4), pp. 32-37.

[15] Crain, N. V., & Crain, W. M. 2010. "Determinants of publication productivity: An empirical analysis." *Public Choice*, Vol, 142(3-4), pp. 265-277.

[16] Dellenback, Y. 2020. "A LOOK AT RESEARCH PRODUCTIVITY: EXAMINING THE RELATIONSHIPS BETWEEN PUBLICATIONS, CITATIONS, AND RESEARCH AND DEVELOPMENT EXPENDITURES", Doctoral dissertation, Johns Hopkins University.

[17] Osipov, G. V., Ponkratov, V. V., Ivlev, V. J., Ivleva, M. I., & Karepova, S. G. 2020. "Factors in managing publication productivity in Russian universities. Humanities and Social Sciences Reviews,", Vol, 8(5), pp. 102-120.

[18] Maharjan, Mohan & Stoermer, Sebastian & Froese, Fabian. 2021. Research productivity of self-initiated expatriate academics: Influences of job demands, resources and cross-cultural adjustment. *European Management Review*. 10.1111

[19] Elango, B., Oh, D.-G., & Rajendran, P. 2021. Assessment of Scientific Productivity by India and South Korea. *DESIDOC Journal of Library & Information Technology,* 41(03), 190-198. https://doi.org/10.14429/djlit.41.03.16558

[20] Singh, Prashasti & Singh, Vivek & Arora, Parveen & Bhattacharya, Sujit. (2020). India's rank and global share in scientific research: how data sourced from different databases can produce varying outcomes?

[21] Singh, Vivek & Arora, Parveen & Uddin, Ashraf & Bhattacharya, Sujit. 2021. India'a Rank and Global Share in Scientific Research: how Publication Counting Method and Subject Selection Can Vary the Outcome?. Journal of Scientific and Industrial Research. 80. 42-50.

Customer Loyalty Model Development of Pool-To-Pool Shuttle Service

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ABSTRACT

The pool-to-pool shuttle service business, both for tourist and business purposes, has continued to grow in recent years owing to the aggressive competition among shuttle services which forces shuttle services to better understand their customers' loyalty. This study seeks to develop a customer loyalty model by considering several factors that influence loyalty such as customer satisfaction, loyalty programs, corporate image, service recovery, perceived safety, price, and service quality. In addition, the effect of differences in the purpose of using the shuttle service was tested on the customer loyalty model. The sample of 384 respondents who have used shuttle services in the last 12 months were used in this study. Sample were divided into two groups, customer for business/college/school purpose and for vacations purpose. Data analysis is performed using multigroup SEM analysis. The SEM results of both of the group show that the absolute fit of the model is adequate judging by the RMSEA value of 0,062 and 0,063 respectively for each group. CFI and TLI which were used as the incremental fit also reach the value of more than 0,9 for both groups which indicate a good incremental fit. Furthermore, from the results showed that there was a significant moderating effect of the difference in the purpose of using the shuttle service on the customer loyalty model. In the group with business/college/school goals, safety perception has no effect on customer satisfaction and company image has no effect on customer loyalty. Customer satisfaction in this group is proven to influence customer loyalty, but the relationship is not stronger than the group with the purpose of using the shuttle service for vacations. In the group with vacation destinations, the perception of safety influences customer satisfaction, but company image has no effect on customer loyalty. Customer satisfaction in this group is proven to influence customer loyalty with a stronger tendency compared to the other group.

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CCS CONCEPTS

• **General and reference** → Document types; Surveys and overviews; • **Social and professional topics** → User characteristics; Cultural characteristics.

KEYWORDS

customer loyalty, shuttle service, loyalty program, safety perception, service recovery

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1 INTRODUCTION

According to [1], transportation is the movement of people or goods using tools or vehicles from and to geographically separated places. In Indonesia, the most developed means of transportation today of land transportation between cities is the shuttle service with the pool-to-pool concept. The concept of this shuttle service business is to move passengers from one meeting point to another, akin to regular bus passenger servce. There is an inherent difference between pool-to-pool shuttle service and regular bus service, especially in Indonesia. Pool-to-pool shuttle service targets the middle-class consumer while regular bus service targets the lower bracket of consumer. This inherent difference creates a gap in the literature because the level of service provided by a shuttle service especially in terms of comfort and punctuality is higher than regular bus service.

The high demand for shuttle service is also served by many pool-to-pool shuttle service with a high degree of competition which forces shuttle service business to be able to better retain customers. The management process regarding customer relationships has also become focus of attention [2].

Customer loyalty is one of the main indicators that will affect competitive advantage in this high degree of competition [3]. Shuttle service businesses must understand the factors that drive customer loyalty [4] and if possible, should not allow customers to switch to another shuttle service [5]. Therefore, this study was conducted with the aim of studying the factors that influence customer loyalty and the relationship among these factors.

Customers on the shuttle service industry also have varied characteristics, such as the difference in the purpose of using the shuttle

service. In general, passengers choose to use the shuttle service for business, school, or college purposes, and for vacations. Passengers with business/college/school purposes tend to have a higher frequency of using the shuttle service than customers with vacation destinations. This characteristic difference according to [6] affect several aspects of loyalty such as the relationship between loyalty programs and customer loyalty. In addition, study in [7] also shows that differences in the purpose of using shuttle services affect the relationship between safety perceptions and customer loyalty. Therefore, these characteristics variations and differences become interesting to be studied in relation to the customer loyalty model.

On an important note, shuttle service industry have positioned themselves as a premium transportation service compared to bus service. This positioning as well as the product and the quality of service being offered, conceivably creates a more analog experience with the product and quality of service offered by the aviation industry rather than a conventional land transportation service offered by bus. With this reasoning, a number of studies performed in the aviation industry were carefully chosen based on the context to explain the factors in managing service in the shuttle service industry.

2 LITERATURE REVIEW

2.1 Customer Loyalty

Reference [8] defines customer loyalty as a commitment to constantly repurchase and subscribe to a product or service in the future despite situational influences. Reference [8] also states that there is a strong relationship between customer loyalty and organizational performance. Lastly, Reference [10] also found a positive economic effect of customer loyalty on firm performance. Therefore, an understanding of customer loyalty for the company is considered important.

2.2 Service Quality

Service quality is generally defined as a standard that shows the conditions when the service delivered is able to meet customer expectations or expectations, needs and satisfaction [11]. Service quality in the transportation industry is related to the ability of transportation service providers to move customers to the desired destination by providing decent service standards [12]. Based on research by [5] and [13], service quality has a significant effect on customer satisfaction. Good service quality will lead to customer satisfaction. Therefore, the following hypothesis is proposed.

H1: Service quality has a positive effect on customer satisfaction

2.3 Price

Based on the result of [5], it is found that price has a significant indirect effect on loyalty through customer satisfaction and corporate image. Customers will be more likely to use a company's transportation services again if the ticket price is considered affordable and the reward is higher on the loyalty program. Reference [2] also stated that price is a determinant of passenger satisfaction. Based on [5], price is one of the determinants of customer satisfaction. This hypothesis is proposed based on those studies.

H2: Price has a positive effect on customer satisfaction

2.4 Perception of Safety

Safety is one of the most important factors in the transportation industry [14] including flights and shuttle services. Safety is an important consideration for transportation customers [7]. The perception of safety for customers with the purpose of traveling for business is different from that for vacations [15]. Therefore, understanding the effects of perceived safety on companies is an important consideration for developing long-term relationships with customers [13]. Therefore, in this study the following hypothesis is proposed.

H3: Perception of safety has a positive effect on customer satisfaction

2.5 Service Recovery

In the shuttle service business, a lot of service failures can occur such as booking errors, lost items, delayed schedules, etc. Service failure can have negative effects on organizational performance, including financial performance (e.g., costs, profitability) and non-financial performance (e.g., customer satisfaction levels, brand equity, poor image, employee burnout, employee morale and emotion, employee job satisfaction) [2]. Reference [16] defines service recovery as a set of actions taken by a company to address customer complaints regarding service failures. Previous studies have stated that service recovery will affect customer satisfaction and customer loyalty as according to research by [2]. Therefore, these two hypotheses are suggested.

H4: Service recovery has a positive effect on customer satisfaction

H5: Service recovery has a positive effect on customer loyalty

2.6 Customer Satisfaction

Reference [17] defines customer satisfaction as an emotional response to the services provided. Furthermore, it is stated in [18] that customer satisfaction is the customer's response in evaluating the perceived difference between expectations and the final result after the consumption process. Other study by [8] also defines customer satisfaction as a cognitive comparison between the expectations that passengers had before using the service and the actual performance of the service. Research by [5] and [13] show that customer satisfaction on airline services has a positive effect on customer loyalty. Therefore, researchers suspect that in the context of shuttle service, satisfaction will also have a positive effect on customer loyalty. Based on the concept and theories explained in this section, this following hypothesis is proposed.

H5: Customer satisfaction has a positive effect on customer loyalty

2.7 Loyalty Program

Loyalty program is a marketing strategy designed to provide incentives for customers to strengthen the continuous purchase [13]. Loyalty program aims to encourage repeat purchasing so as to improve customer retention rates by offering benefits to increase frequency and amount of purchases [19]. There are studies that try to study the relationship between loyalty programs and customer loyalty, as [6] and [13] which show that the loyalty program influences customer loyalty. These notions suggest this following hypothesis.

H6: Loyalty program has a positive effect on customer loyalty

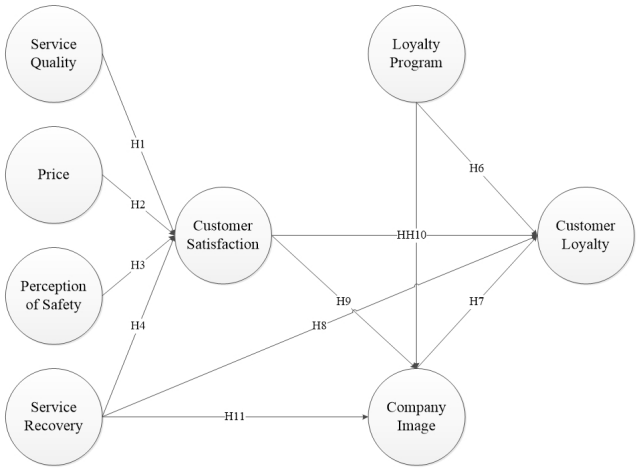

Figure 1: Research Model Framework

2.8 Corporate Image

Corporate image is defined as the overall impression formed in the public's mind about a company [5]. Satisfied customers can leave good reviews of the company and recommend it to others. Reference [5] also mentions that the company's image affects customer loyalty. In addition, Reference [20] states that there is a relationship between loyalty programs and corporate image. A good loyalty program can build a good image in the minds of customers. Successful service recovery can also affect the company's image [21]. Therefore, in this study, the following hypotheses will be tested.

H7: Company image has a positive effect on customer loyalty
H9: Customer satisfaction has a positive effect on company image
H10: Loyalty program has a positive effect on company image
H11: Service recovery has a positive effect on company image

3 RESEARCH METHODOLOGY

3.1 Model Development

The research model was adopted from the models in aviation services. The model in aviation services was chosen because it has similar characteristics to the pool-to-pool shuttle service because both are in the transportation industry and there has been no research on customer loyalty models in the pool-to-pool shuttle service. The research model framework was formed based on the 4 previous models, namely the research model of [5], [7], [2] and [13]. This study combines the four models by making the model of [5] as the basic model and add variables of perceived safety, service recovery and loyalty programs into the basic model.

The effect of differences customer purpose on the customer loyalty model, business, and leisure purpose are also considered. The selection of these characteristics was carried out based on previous research ([6]; [7]). The research model framework based on the previous models is shown in Figure 1.

3.2 Data Collection and Analysis

The approach used in this study was cross-sectional. The sample is collected from Xtrans and DayTrans customers who have used the shuttle service for the last 12 months. Xtrans and Daytrans' respondents are chosen because these two shuttle services have an ongoing loyalty program. A questionnaire is developed based on operationalization of construct compiled from [2], [5], [7], [11], [13], and [21] adapted to the context of pool-to-pool shuttle service business. The data analysis was performed using Structural Equation Modeling (SEM) multigroup analysis method with the maximum likelihood estimation (MLE) estimation method. The sample size used in this study is 384 respondents with 211 respondents in group 1 (business/college/school) and 173 respondents in group 2 (vacation).

4 FINDINGS AND DISCUSSION

The model was first checked for its validity and reliability first, before analyzed structurally using SEM. The validity test was checked to determine whether the research instrument that had been developed accurately explain the constructs being studied. Three steps of validity tests were performed on the research instrument. The first was content validity by examining every indicator used in the instrument in a qualitative manner by using expert judgment. Afterwards, a convergent validity test using Pearson Correlation was used on the research instrument. The result of this test showed that only one indicator, measuring the construct of Service Quality that failed the test, which later was omitted from the instrument to improve the convergent validity. Lastly, the discriminant validity was tested by measuring the correlations of indicators in a construct to other constructs in the model. The result of the test showed that every indicators in the instrument passed this test.

The reliability test used in this study also showed that every construct used in the model had a high-degree of reliability. This conclusion was reached based on the Cronbach's Alpha, the measure for internal consistency, of every construct to be above the minimum required value of a reliable construct.

After validity and reliability of the research instrument had been deteremined to be adequate, the data analysis was then continued to the measurement model test. The results of the measurement model test show that the model is declared fit, and the indicators used are appropriate to measure the specified construct. The construct validity test was carried out by considering three aspects, the standardized loading, AVE (Average Variance Extracted), and CR (Construct Reliability). The indicators in this study were proven to be valid.

The measurement model invariance is then analyzed in 4 stages, namely configurational invariance, weak measurement invariance, strong measurement invariance, and strict measurement invariance. This invariance test is a prerequisite to compare and interpret differences between groups. Configuration invariance testing was conducted to ensure that the indicators used in the study measure the same construct between groups. The configuration model also has a good fitness model. The RMSEA value is below 0.08. The CFI and TLI configuration models were also above 0.9.

Next, testing the structural model. The structural model discusses the relationship between the constructs that exist in each group and the invariance that exists in the relationship between groups. A summary of the basic model fitness results for each group is listed in Table 1.

Table 1: Summary of the basic model fitness

	Group 1 (Business/College/School)	Group 2(Vacation)
Basic goodness of fit		
$\chi 2$ (Chi Square)	962,034	898,221
Degree of Freedom	526	527
P-Value	<0.0001	<0.001
Absolute fit		
RMSEA	0.063	0.064
90% Confidence Interval	0.056–0.069	0.057–0.071
Incremental fit		
CFI	0.941	0.932
TLI	0.933	0.924

Table 2: Summary of the basic model fitness, accepted hypotheses are marked with *

Hypotheses	**Estimated Coefficients**	
	Group 1 (Business/College/School)	**Group 2 (Vacation)**
H1	0.721*	0.352*
H2	0.188	0.056
H3	-0.139	0.571*
H4	0.199*	0.015
H5	0.482*	0.746*
H6	0.062	0.139*
H7	0.417*	0.082
H8	-0.026	0.035
H9	0.538*	0.667*
H10	0.186*	0.113*
H11	0.231*	0.173

The hypothesis tested on the structural model contains a direct *effect* of the 8 constructs. The results of hypothesis testing are shown in Table 2.

From the result of group 1, in this group, there are not enough empirical evidence to suggest price and perceived safety influence service quality. In addition, service recovery and loyalty programs also do not have a direct significant effect on customer loyalty. However, the loyalty program is empirically proven to affect the company's image in this group and the company's image is also empirically proven to affect customer loyalty. In group 2, service recovery had no significant effect on the overall model. Service recovery does not affect customer satisfaction, company image, or loyalty directly to respondents who tend to use shuttle service less frequently. Company image in this group also does not affect customer loyalty. The shuttle service ticket price also does not affect the level of customer satisfaction in group 2.

Furthermore, the structural model invariance test was carried out on the direct and indirect relationship between constructs. The null hypothesis in this test is that there is no difference in the relationship between one construct and another in different group. The estimator used in testing this model is MLMV and the test is carried out with the Wald Test statistic at a significance level of 0.05. The hypothesis is accepted if the p-value is more than 0.05. The results of the measurement model invariance test are shown in Table 3.

There are 3 hypotheses that are rejected, $H_{0\text{-}3}$, $H_{0\text{-}5}$, $H_{0\text{-}7}$. This shows that in these 3 hypotheses, there is a significant group difference effect. Group differences affect the relationship between perceived safety and customer satisfaction. In group 1, the perception of safety has no significant effect on customer satisfaction, while in group 2 the perception of safety is empirically proven to affect customer satisfaction. In addition, group 2 is also more sensitive to what is felt when using the shuttle service. Therefore, in this group the perception of safety is a determinant of customer satisfaction.

The construct of customer satisfaction in both groups has a significant effect on customer loyalty. However, when viewed from the results of structural model *invariance* testing, it is found that there is a difference in the relationship between customer satisfaction and customer loyalty. Even though they are both equally influential, customer satisfaction in group 2 has a significantly greater influence on customer loyalty than group 1. The effect of customer satisfaction on loyalty is more pronounced in group 2. In addition, there is a difference in the relationship between the influence of corporate image constructs on customer loyalty between groups. In group 1, company image directly affects customer loyalty, while

Table 3: The results of the measurement model invariance test

Hypothesis	Research Hypothesis	*Walds Test*	*P-Value*	Conclusion
H_0 -1	SQ→CS	2,400	0.121	accepted
H_0 -2	PR→CS	2,547	0.111	accepted
H_0 -3	SP→CS	16,566	0.000	rejected
H_0 -4	SR→CS	0.986	0.321	accepted
H_0 -5	CS→LO	4,958	0.020	rejected
H_0 -6	LP→LO	0.455	0.500	accepted
H_0 -7	IM→LO	5,872	0.015	rejected
H_0 -8	SR→LO	0.194	0.660	accepted
H_0 -9	CS→IM	1,642	0.200	accepted
H_0 -10	LP→IM	2,618	0.106	accepted
H_0 -11	SR→IM	0.176	0.675	accepted

in group 2 company image does not significantly affect customer loyalty.

From the results of the structural model invariance test between the groups, it can be concluded that there is a significant moderating effect of the different purposes of using the shuttle service on the research model. The relationship that is influenced by the difference in the purpose of using the shuttle service is the relationship contained in the 3 rejected hypotheses.

5 CONCLUSION

Based on the analysis carried out in this study, it can be concluded that the factors that have been shown to influence customer loyalty shuttle service are service quality, perceived safety, service recovery, customer satisfaction, loyalty programs and corporate image. Furthermore, the effect of differences in the purpose of using the shuttle service affects the relationship between service recovery to customer satisfaction and corporate image and customer satisfaction to customer loyalty. In the group with business/college/school goals, safety perception has no effect on customer satisfaction and company image has no effect on customer loyalty. Customer satisfaction in this group is proven to have an effect on customer loyalty, but the relationship is not stronger than the group with the purpose of using the shuttle service for vacations. In the group with vacation destinations, the perception of safety influences customer satisfaction, but company image has no effect on customer loyalty. Customer satisfaction in this group is proven to influence customer loyalty and the relationship is stronger when compared.

Based on the analysis and the limitations of existing research, there are several suggestions that can be made for further research, such as grouping respondents in other segments such as price or income and using a longitudinal research approach so that the impact of time can be captured.

REFERENCES

[1] Streenbrink, PA, 1974. Optimization of Transport Networks. *John Wiley & Sons.*

[2] Akamavi, RK, Mohamed, E., Pellman, K. & Xu, Y., 2015. Key determinants of passenger loyalty in the low-cost airline business. *Tourism Management,* Volume 46, pp. 528-545.

[3] Wirtz, J., Mattila, AS & Lwin, MO, 2007. How effective are loyalty reward programs in driving share of wallet?. *Journal of Service Research,* Volume 9, pp. 327-334.

[4] Mikulic, J. & Prebezac, D., 2011. What drives passenger loyalty to traditional and low-cost airlines? A formative partial least squares approach. *Journal of Air Transportation Management,* Volume 17, pp. 237-240.

[5] Calisir, N., Basak, E. & Calisir, F., 2016. Key drivers of passenger loyalty: A case of Frankfurt Istanbul flights. *Journal of Air Transport Management,* Volume 53, pp. 211-217.

[6] Ringle, CM, Sarstedt, M. & Zimmermann, L., 2011. Customer Satisfaction with Commercial Airlines: The Role of Perceived Safety and Purpose of Travel. *Journal of Marketing Theory and Practice,* Volume 19, pp. 459-472.

[7] Oliver, R., 1997. *Satisfaction - A behavioral perspectiva on the consumer.* s.l.:McGraw Hill.

[8] Lindenmeier, J. & Tscheulin, K., 2008. The effects of inventory control and denied boarding on customer satisfaction: the case of capacity-based airline revenue management. *Tourism Management,* Volume 29, pp. 32-43.

[9] Reichheld, F. & Sasser, W., 1990. Zero defects: quality comes to services. *Harvard Business Review,* Volume 68, pp. 105-111.

[10] Leong, L.-Y., Hew, T.-S., Lee, V.-H. & Ooi, K.-B., 2015. An SEM–artificial-neural-network analysis of the relationships between SERVPERF, customer satisfaction and loyalty among low-cost and full-service airlines. *Expert Systems with Applications,* Volume 42, pp. 6620-6634.

[11] Suki, NM, 2014. Passenger satisfaction with airline service quality in Malaysia: a structural equation modeling approach. *Research of Transportation Business Management,* Volume 10, pp. 26-32.

[12] Sandada, M. & Matibiri, B., 2016. An Investigation into The Impact of Service Quality, Frequent Flier Programs, and Safety Perception on Satisfaction and Customer Loyalty in The Airline Industry in Southern Africa. *South East European Journal of Economics and Business,* Volume 11, pp. 41-53.

[13] Manvichien, C., 2015. Vitality of Safety Factors: A Case Study of Thai Airways. *Procedia - Social and Behavioral Sciences,* Volume 197, pp. 2103-2109.

[14] Siomkos, GJ, 2000. Managing Airline Disasters—The Role of Consumer Safety Perceptions and Sense-Making. *Journal of Air Transport Management,* Volume 6, pp. 101-108.

[15] Gronroos, C., 1990. Relationship approach to marketing in service contexts: The marketing and organizational behavior interface. *Journal of Business Research,* Volume 20, pp. 3-11.

[16] Yi, Y., 1990. A critical review of consumer satisfaction. *Review I Marketing,* pp. 68-123.

[17] Tse, D. & Wilton, P., 1988. Models of consumer satisfaction formation: An extension. *Journal of Marketing Research,* Volume 25, pp. 204-212.

[18] Lewis, M., 2004. The influence of loyalty programs and short-term promotions on customer retention. *Journal of Marketing Research,* Volume 41, pp. 281-292.

[19] Kang, J., Alejandro, TB & Groza, MD, 2015. Customer–company identification and the effectiveness of loyalty programs. *Journal of Business Research,* Volume 68, pp. 464-471.

[20] Park, J.-J. & Park, J.-W., 2016. Investigating the effects of service recovery quality elements on passengers' behavioral intention. *Journal of Air Transport Management,* Volume 53, pp. 235-241.

Circular Economy In Recycled Paper Company

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ABSTRACT

The paper industry is an industry that has high economic value. In the past, the use of wood-based virgin pulp was still the principal ingredient in the paper production process, but with increasing global awareness of its negative impact, the paper industry has switched to using paper waste as the main raw material. The increasing adoption of technology and the cheaper recycled paper prices are driving this movement even more. Using recycled paper as its raw material goes through several more processes to be used as raw material for making fresh paper. In the production process, waste material will appear as water, plastic, sludge (mud), ink, and so on. Currently, waste management and reuse of various kinds of remaining production are still not optimal. The Paper Industry (PI) company is a paper company that produces over 40 tons of plastic waste per day from recycled paper. So far, PI has been trying to manage the waste by using an incinerator, which is then reused as a source of steam for the production process. However, the intake from the process is still insufficient and, economically, it is still more profitable to use coal as the main raw material for the boiler. This is only one of many side products that should still be reusable. Therefore, researchers want to apply Circular Economy (CE) as a solution to this problem. Circular Economy (CE) was chosen as a tool to optimize production processes, design processes, and company operations. The CE approach is projected to have an overall positive impact on the PI. With its application, PI will get an economic surplus, improve the welfare of workers and residents, and maintain environmental conditions due to waste reduction.

CCS CONCEPTS

• **General and reference** → Document types; General conference proceedings; Cross-computing tools and techniques; Estimation; Document types; Surveys and overviews.

KEYWORDS

Circular Economy, Recycled Paper, Paper Industry

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1 INTRODUCTION

When the world is dealing with limited natural resources, the industrial sector is building a circular economy to sustain itself, and the paper and pulp industry is one of the pioneers in adopting this approach. This model is very popular in the pulp and paper industry, in contrast to the traditional (take and make) linear economy, the paper industry is currently developed under the (reuse & recycle) model. "Paper is always recycled," says Jori Ringman, deputy director of the European Federation of Paper Industries, a non-profit organization. The Circular Economy approach continues to contribute to the industry today as paper companies begin to buy back paper from local governments and ensure that recyclable materials are always available. Paper cannot be recycled forever, the natural fibers used in the paper have wear properties after 5 to 7 times of recycling. This is because not all paper is returned to the paper company and the recycling, collection, and sorting processes have been lost. The pulp and paper industry has the advantage of being at the forefront of promoting the Circular Economy concept. For the wider economy, CE offers many opportunities for those willing to invest their time and energy.

Circular Economy has attracted many researchers to conduct research in various industrial fields, one of which is the research conducted by Adi Wicaksono & Ahmad Kadafi [1], who researched CE in the Glass Industry by using cullet derived from the reuse process or reject products. In addition to the glass industry, the CE concept is also developing in the construction industry. This CE practice in the construction industry aims to reduce the amount of waste generated at the end of a building's life cycle [2]. The transition to CE was also implemented in the textile and clothing industry [3].

The pulp & paper industry in Indonesia is a significant contributor to the national economy. The paper industry in Indonesia is ranked 8th among pulp producers in the world and 6th position for the largest paper producers in the world. From this, it can be seen, that the Indonesian pulp and paper industry can play a major role in increasing national economic growth.

The process of making paper with paper waste as raw material goes through several stages of the process to obtain the expected product results. In general, 9 processes will be passed by the paper waste that will be reproduced as you can see in figure 1. These processes are the collection and sorting of raw materials, pulping process, screening, de-inking, stock preparation, Wet End Process, Dry End Process, coating, and paper output

CE undoubtedly promises the sustainability of the surrounding environment, but also needs to meet business needs to be called a successful business model in the future. Many cases prove that the

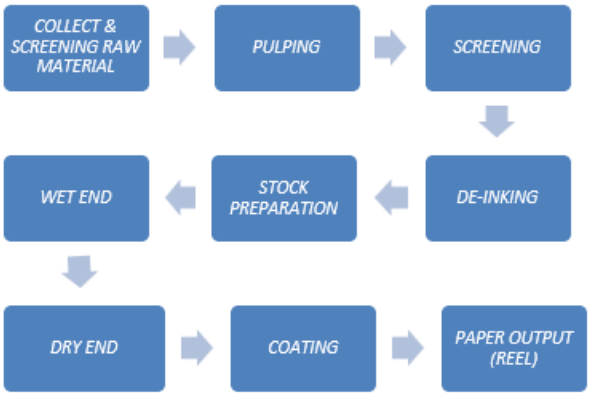

Figure 1: Recycle Paper Production Process

circular economy is good for the environment as well as for profit. Adopting CE can reduce risk and increase system resilience through differentiating business models, separating economic development from resource use and environmental impact, and anticipating increasingly stringent environmental regulations and changing consumer preferences. The research question for this paper is how the circular economy can give a financial impact on paper recycling companies.

2 LITERATURE REVIEW

2.1 Circular Economy Theory

A Circular Economy is a production and consumption paradigm in which materials and goods are currently shared, rented, reused, restored, revised, and recycled indefinitely. Therefore, the product life cycle can be extended. When a product reaches the end of its useful life, its ingredients are reused whenever possible. , adding that CE is an updated economic model of its engineering process, and has the aim of keeping products, components, and materials at their disposal.

Reuse refers to the reuse of a product in its entirety or some of its components after the first life cycle of the product has ended. Recycling is the process of changing materials that will be considered waste into raw materials or new products. The redesign includes activities to change the design of a product, which will use components, materials, and resources that have been recovered from the previous process. Reduce focuses on the initial process of the product life cycle, efficient use of resources at the pre-manufacturing stage, the efficiency of energy, materials, and other resources during the production process, as well as reducing emissions and waste when using the product. Remanufacture itself refers to the reprocessing of a used product to its original condition again by using as much of the old part of the product as possible.

2.2 Material Flow Analysis

Material Flow Analysis is an analytical approach for calculating the flow and stock of material or units in a well-defined system. An MFA system is an engineering model of a manufacturing facility,

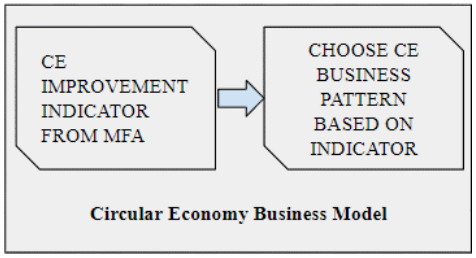

Figure 2: CEBM's Approach For Value Proposition

manufacturing sector, or specific geographic area. The scope of the system model information is adjusted to the research objectives. An MFA system always consists of a boundary system, one or more processes, the flow of material between processes, and a material inventory in the process. The development of the closed-loop system at CE is based on knowledge of how materials move within the system [4].

Therefore, the development and use of MFA are essential for measuring flow through this environment [7]. An MFA can be useful in terms of offering opportunities for legal, regulatory, and efficiency action, identifying environmental issues, and providing technical data for decision making and planning. The graph represents aggregated data that serves as a starting point for a more thorough MFA. Graphs can be used to extract the CE indicator. [5]

2.3 CE strategic management tools

The circular economy challenges companies to rethink supply chains and business models. Several frameworks in the academic and practical literature offer Circular Economy Business Models to rethink how companies create value while adhering to CE principles. Lüdeke-Freund et al. (2019), created a morphology that integrates and unifies the current range of CEBMs [6]. Simultaneously, the CEBM database is analyzed to find possible business model designs or available options for designing business model dimensions such as value propositions or value delivery systems.

3 RESEARCH METHOD

3.1 Data Acquisition

- Raw Material usage: Material used as the main component for recycled paper production, contain OCC (Old Corrugate Card), NCC, water, and chemicals.
- Process Value: Goods that move in the process of paper makings, such as white water, steam, and paper pulp.
- Waste data: In the form of a collection of production waste data components (reject products, sludge, plastics, and others)
- Output Product: The results of the production, finished goods that will be sold to consumers either locally or for export.

3.2 Data Processing

The data that has been collected, can then be used to monitor the use and loss of raw materials, use of chemicals, and process waste flows. However, before all that, it is necessary to understand the

flow and process of the production of paper waste. From this flow, the balanced flow in the paper production system can be obtained. From the diagram, data can be analyzed the opportunities that can be selected for CE Business Model planning that can provide benefits to the company as seen on figure 2. To visualize & evaluate the CEBM planning then we will use the Business model Canvass as a tool to meet those needs

4 RESULT & DISCUSSION

4.1 PI Waste Management Cost

One of the most difficult problems facing PI today is waste management. The use of landfills as a location for storing waste and environmental pollution that arises if not managed properly will cause financial losses and impacts on the company. Every day, PI produces approximately 350 tons of paper. Of this production, 15% of the result is lost waste, material waste in the form of rejected products, process wastewater, and sludge will partly be reused in the process.

PI production waste is divided into 4 types, namely liquid, gas, particulate, and solid waste. Every month, an average of 750 tons of remaining production appears or approximately 5% of total production, costing the company around. The required management fee itself is not small, based on the 2021 financial report from PI, the overhead cost for waste treatment reaches IDR 2.041.522.605,- per month. This number will increase with increasing PI production capacity.

4.2 MFA of a PI production system

In making MFA, it is necessary to have system limits to obtain specific results according to the system being analyzed. Determination of the process is taken based on changes in the type of goods in the production process flow, import value means goods enter from outside the system boundaries into the system, and export value means goods come out of the system to outside the system. PI production process then separated into 5 different processes, that is Stock Preparation Process, Paper Factory Process, Water Treatment Plant, Coal Boiler dan Waste processing

After knowing the limits of the system to be analyzed, the quantity of each item or substance that moves in the system through each process can be given. Value quantity data is obtained from the PI paper production process in 2021, starting from August – December. The units of measurement used are ton and m3.

From the figure 3, we see multiple inputs of process, shown using symbol I (import), and output (goods/substance that going out of the system) shown as E (export). To see the performance of each process we use mass balance calculation. The Mass Balance calculation for each process is then carried out using the formula:

$$\sum input - \sum output = ds\ stock - ds \geq 0$$

Where:
stock=Number of goods keeps within process (T)
ds=Difference number of goods based on input and output of process (T)

From the calculation above, it is known that if an overstock value appears, there will be an additional cost to meet the stock needs of the process. From the diagram, it can also be seen that there are

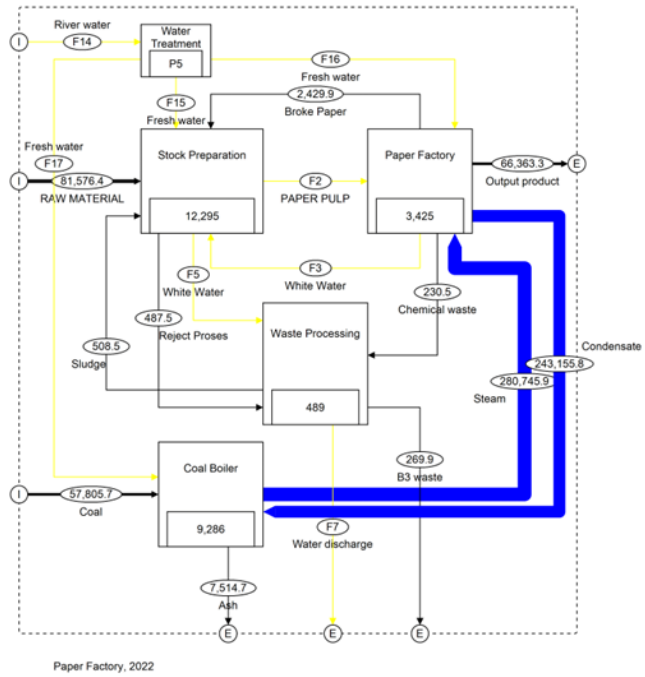

Figure 3: Mass Flow Analysis PI Production System

losses that occur due to the production process, for example, steam loss, and fiber loss which are wasted in the water discharge process.

For P1 (Stock Preparation) the difference between input and output is 121,693.167 tons with stock in inventory data of 102,576 tons and a stock capacity of 250,000 tons, the loss of the production process that appears is 15.7%. For P2 (Paper Factory), the difference between the input and output process is 113,658 tons with stock in inventory data of 103,479 tons and stock capacity of 170,000 tons. Production process loss appears at 8.95%. For P3, (waste processing) it is known that the difference between input and output values is 11,748 tons with stock in inventory data of 10,489 tons and stock capacity of 10,500 tons. Appears loss of 10.7% from the processing. For the process in the coal boiler unit (P4), the difference between input and output is 17,620 tons and the stock in inventory data is 14,286 tons. The stock capacity of the coal boiler can accommodate 25,000 tons of units. It is known that the process loss is 18.9%. Lastly, in P5 (Water Treatment), it is found that the difference between the input and output of the system is 100,171 m3 and the stock in inventory data is 100,872 m3. The capacity of the water pool for this unit is 120,000 m3, it is known that the data difference is 0.67% (recording error)

From the mass balance analysis, we can make some conclusions:

- There is a loss in every production process, for every loss that occurs and is not recorded, most of these components will be iterated in the process (except gas loss (steam), and particulate loss) due to the absence of recording of ditch discharge and internal storage ponds in the PI.

- Overcapacity is found in the waste treatment unit, there is a loss in the process of 10%, this is estimated because the process of using sludge is less than optimal.
- In the waste processing unit, there is process rejects that cannot be processed, mainly rejects in the form of plastic, wire, and secondary sludge.
- The biggest loss is in the coal boiler process unit, there are 3334.8 tons losses in this process. In addition, most of the losses in this unit cannot be iterated because they are in the form of gas loss and particulate loss.

4.3 Circular Economy Business Model

The CE approach in forming a business model is carried out using the 6R, Reuse, Recover, Recycle, Redesign, Reduce, & Remanufacture principles. Based on the MFA, it can be determined the approach taken to increase the company's financial benefits, both from better resource utilization, production waste reduction, and reuse of generated waste. There are 3 improvement plans proposed based on MFA Analysis.

- Reduction of fiber loss in each production process (Recover, Reuse)

In the PI production process, there was a loss of 15.7% in the Stock Prep unit and 8.9% in the Paper Factory unit. This fiber loss can be carried up to the discharge point outside the system and cause the risk of water pollution in the surrounding environment. The potential loss arising from these 2 units is 3,000 tons of fiber or Rp. 15,000,000,000 per year. Steps that can be taken are the addition of screens on the SP and PF processing units, in addition to decreasing the Disc Refiner press parameters on the SP unit.

- Optimization of steam usage (Redesign, Reduce, Reuse)

In the PF process unit at PI, the use of steam uses cascade system technology which has a simple operational and piping process, but the application of energy provided cannot be maximized. It is recommended to change the system from a cascade to a thermos-compressor which is more efficient in energy use and its application can be more controlled to reduce the possibility of rejecting the paper. In addition, the use of a Thermo compressor can maximize condensate return in the system.

- Plastic Pallet unit (Recover, Recycle, Redesign)

Plastic pallet units can solve the problem of plastic waste that is increasingly piling up at PI. Due to insufficient output of waste by using it as boiler raw material, the current condition of plastic waste is increasingly piling up and becomes the company's morning burden. An area of 2000 m2 of potential land by the company cannot be utilized because it is used as a location for storing plastic waste or if it is converted to around IDR 175,000,000 per year. In addition, there are government regulations regarding the prohibition of the disposal of plastic waste out of factories, causing the need for a permanent solution to resolve the buildup of this plastic waste. Based on the calculations, it is estimated that there will be a difference between input and output in the system of 100 tons per month.

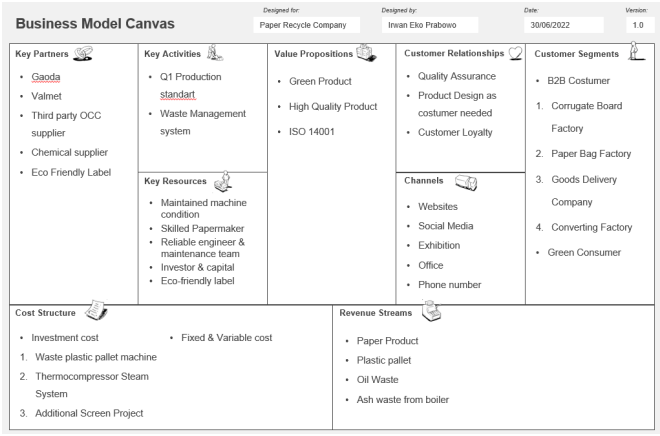

Figure 4: Business Model Canvass based on CEBM

4.4 Business Model Canvass based on CEBMs

The business model canvass is prepared based on the proposed CEBM, there are 3 proposed improvement proposals, namely the manufacture of waste plastic pallet units, changes to the Thermo compressor steam system, and additional screens on the PF PI. These 3 improvement plants will become investment cost as value delivery to help PI Improve its's standard as a paper company while keep increasing profitability as we can see on figure 4

5 CONCLUSION

Based on the discussion regarding the benefits of a Circular Economy on Recycled Paper Companies related to MFA, CEBM, and BMC that has been carried out, the following conclusions are obtained:

- Through MFA it is known that there are losses that appear in every process in the PI production system, this can be corrected by optimizing the production process, and reducing production waste. As a result, a higher level of productivity will be obtained, which will increase company profits
- From the results of the MFA analysis, a CE-based business model approach was taken which resulted in 3 improvement plans, namely :
- Waste Plastic Pellet Machine
- Thermocompressor Steam System
- Additional screen Projects

The author knows that the results of the research carried out are not perfect, therefore several points can be considered further for PT. PI can increase their awareness of environmental conditions and waste management in the company. In the future, this condition will be a burden for the company to grow bigger due to the increasing environmental costs that must be borne by the company. In further research, it is possible to examine further the sub-system process in each process, considering that the results of this research show that the loss value is quite high in each process.

REFERENCES

[1] P. Adi Wicaksono and C. Ahmad Kadafi, "The Improvement of Production Process Impact in Furniture Industry Toward Circular Economy," E3S Web Conf., vol. 202,

2020, doi: 10.1051/e3sconf/202020207052.

[2] G. L. F. Benachio, M. do C. D. Freitas, and S. F. Tavares, "Circular economy in the construction industry: A systematic literature review," J. Clean. Prod., vol. 260, 2020, doi: 10.1016/j.jclepro.2020.121046.

[3] M. Koszewska, "Circular Economy - Challenges for the Textile and Clothing Industry," Autex Res. J., vol. 18, no. 4, pp. 337–347, 2018, doi: 10.1515/aut-2018-0023.

[4] P. H. Brunner and H. Rechberger, "Material Flow Analysis B o o k Reviews Practical Handbook of Material Flow Analysis," Waste Manag., vol. 9, no. 5, pp. 337–338, 2004.

[5] G. Moraga *et al.*, "Circular economy indicators: What do they measure?," Resour. Conserv. Recycl., vol. 146, no. April, pp. 452–461, 2019, doi: 10.1016/j.resconrec.2019.03.045.

[6] F. Lüdeke-Freund, S. Gold, and N. M. P. Bocken, "A Review and Typology of Circular Economy Business Model Patterns," J. Ind. Ecol., vol. 23, no. 1, pp. 36–61, 2019, doi: 10.1111/jiec.12763.

[7] A. Marques, J. Cunha, A. De Meyer, and K. Navare, "Contribution towards a comprehensive methodology for wood-based biomass material flow analysis in a circular economy setting," Forests, vol. 11, no. 1, 2020, doi: 10.3390/f11010106

Submission Template for ACM Papers

Prioritize Business Process Improvement Plan using House of Quality and Modified House of Risk: a Case Study of Higher Education Institution (HEI) from Indonesia

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ABSTRACT

Higher Education Institutions (HEIs) must be able to operate effectively, efficiently and focus on customers and make continuous improvements. In conducting an improvement plan, an analysis of potential risk events and risk agents are required. In addition, the improvement plan must also be oriented towards performance indicators. This article discusses business process planning at HEIs and prioritizing improvement plans. The House of Quality (HoQ) is used to calculate the relation value between business processes and key performance indicators of HEI. while the modified House of Risk (HoR) is used in prioritizing improvement plan alternative. Aggregate Risk Potential (ARP) score is a parameter to prioritize improvement. The result show that ARP score are range from 180 – 13,824. In this case, most of the risk agent improvement priorities are related to research activities: lack of research ability, lack number of research and community services proposals, research group does not establish or inactive, and low research culture.

CCS CONCEPTS

• **Social and professional topics** → Quality assurance.

KEYWORDS

Higher Education Institution (HEI), business process, risk, Modified House of Risk (HoR)

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1 INTRODUCTION

Nowadays, competition between universities is getting tougher. Universities must be able to use resources effectively and efficiently. HEI must establish better ways for teaching and learning, raise student proficiency, put the customer first, and make better use of all available resources. [1]. On the other hand, HEI must also be customer-oriented [2]. Customers of HEI consist of owners, student families, university leaders and employees, suppliers, high schools, other universities, industry, state, government, taxpayers, and professional organizations as well as family [3], [4]. HEI should focus on customer expectations. By knowing the customer expectations, HEI can prepare strategies to improve related business processes. Students are the main customers at HEI. For this reason, every HEI must know the expectation of students and translate them into operational activities. Student expectations were identified by [5] and then converted into action plans. Several other researchers have determined what students expected and suggested improvement plans [6]–[10]. Several studies used quality function development (QFD) and kano model to perform improvement analysis in [5], [6], [9], [10].

Risk management is used in many facets of contemporary life, including banking, finance, health, life, business initiatives, and project management. Risks included uncertainty regarding future government funding, an increase in post-graduate enrollment, a desire to rank highly among universities worldwide, increased competitiveness to attract top-notch international students, and international competition in research, teaching, and learning [11]. Meanwhile, the association of college and university business officers (NACUBO) defines risk as issues that affect an organization's ability to achieve goals [12]. Risk assessment is a process to evaluate and assess the magnitude of risks and the possibility of risks. The goal is to rank the risk as the basis for appropriate action. This allows universities to focus on managing significant risks [13]. Risks faced by universities are divided into strategic risks and operational risks. Risks associated with internal university governance, dangers posed by the external environment in which the university operates, and outcomes of university operations are all considered strategic

risks since they have an impact on the entire university. Operational risks are those that are connected to tasks performed by academic units and/or administrative divisions to carry out key academic activities including learning, teaching, and research as well as to manage the university's operations and resources [11]. House of risk (HoR) is a concept developed by Pujawan & Geraldin (2009). HoR made the company possible to decide which risk agents to manage and to prioritize taking preventative measures to lessen the total impact of risk events caused by those risk agents. Initially, the HoR model was developed and used in supply chain management (SCM), but some researchers used HoR in product development [15]–[17] and services [18]. This article discusses how to prioritize a business process improvement plan in using house of quality and modified house of risk (HoR).

2 METHODOLOGY

HOR consists of HOR1 and HOR2. HOR1 is used to determine which risk agents are to be given priority based on the Aggregate Risk Potential (ARP) score. HOR2 will prioritize the actions considered effective but with reasonable money and resource commitments. This article adopts HOR1 to prioritize a business process improvement plan [14]. Steps in developing HOR1 are as follows:

a. Identification of business process. In term of Indonesia HEI, the business process consist of three activities namely Teaching, Research, Community Services, and Supporting Activities.
b. Identification of risk events and risk agents of each business process.
c. The next step is calculating the ARP score to determine the priority of the risk agent that must be improved. Pujawan & Geraldin [14] used equation (1) to calculate ARP.

$$ARP_j = O_j \sum_i S_i R_{ij} \tag{1}$$

Oj is the occurrence probability of risk agent j; Si is the severity of impact if risk event i occurred, and Rij is the correlation between risk agent j and risk event i. Determining the probability (Oj) can be done if the risk agent has ever occurred. But a risk agent may never have happened. Meanwhile, the Quality of higher education (HE) has been the most critical issue. The performance-based evaluation of HEI is one of the most critical concerns. Several countries have implemented performance-based systems for measurement and funding [19]. So, every improvement should always refer to performance indicators. In the context of HEI in Indonesia, the Minister of Education and Culture of the Republic of Indonesia established key performance indicators of HEI called Indikator Kinerja Utama (IKU). These indicators are a new performance measure for universities to realize adaptive universities with more outcome-based learning. Indikator Kinerja Utama (IKU) consist of [20]:

1) Graduates Get Decent Jobs (IKU1)
2) Students Gain Off-Campus Experience (IKU2)
3) Lecturers Doing Activities Outside the Campus (IKU3)
4) Practitioners Teaching on Campus (IKU4)
5) Lecturer's Work Are Used by The Community or Get International Recognition (IKU5)
6) Study Program Collaboration with World-Class Partners (IKU6)
7) Collaborative and Participatory Classes (IKU7)
8) International Standard Study Program (IKU8)

So, in this article to calculate ARP, equation (1) is modified by replacing Oj with the total relationship value of business process with performance indicators because performance indicators are more relevant than occurrence. The equation (1) is modified to equation (2).

$$ARP_j = P_j \sum_i S_i R_{ij} \tag{2}$$

Where P_j is the total relationship value business process j with performance indicators. Si value between 1 – 10 where 10 represents extremely severe. Rij is the relationship between each risk agent and each risk event. The relationship rated as 9 (strong), 3 (medium), 1 (weak), or 0 (no relationship). The House of Quality (HoQ) model is used to calculate the total relation value of business process j with IKU. IKU is a requirement (what) and risk event as a technical feature (how). The relationship value between each business process and IKU consists of 9 (strong), 3 (medium), 1 (weak), or 0 (no relationship). Assessment is carried out using the format in Table 1. Hij is the relationship value between IKU i and business proses j. HOR model is presented in Table 2.

The next step is the calculation of the ARP score. The complete calculation of ARP can be seen at House of Risk (HOR1) in Appendix 2. Calculation of the ARP value using equation (2). As an illustration for calculating the ARP value, risk agent A1 (low motivation to study for doctoral degree) has strong relation (9) with six risk events, each with the degree of severity 10, 5, 8, 3, 8, 5 and medium relation (3) with two risk agents with a degree of severity 6 and 5. The ARP value can be calculated as follows:

$$\text{ARP1} = 36\text{x}\left[9\,(10+5+8+3+8+5)+3\,(6+5)\right] = 13,824$$

The ARP value of other risk agents and their rankings can be seen in Appendix 2. ARP value ranges from 180 – 13,824. Six risk agents that contribute 80 % to the total ARP value will be analyzed further. The six risk agents are low motivation to study doctoral degree (A1), lack of research ability (A2), lack number of research and community services proposals (A12), the university does not have good relations with industry (A6), research group does not establish or inactive (A13), and low research culture (A19). Furthermore, it is necessary to analyze several alternative actions plan to improve each risk agent. Lecturers holding doctoral degrees are important indicators of HEI accreditation and ranking. Several efforts can be made to increase the motivation of lecturers to continue their doctoral education, for example, the provision of incentives and an attractive payroll system for lecturers holding doctoral degrees. To improve good relations with the industry, several actions can be taken, for example, holding industry gatherings, joint activities, and inviting industries to give guest lectures. Meanwhile, risk agents A2, A12, A13, and A19 are associated with an increase in the number of scientific research and publications. The number of scientific research and publications is also an indicator of HEI accreditation and ranking. Increasing the number of scientific publications can be carried out with several activities, including providing coaching for writing international journals, writing research proposals, and establishing research groups.

Table 1: HoQ Model

IKU (what)	Business Process (how)			
	BP1	BP2	. . .	BPj
IKU1	H11	H12	...	H1j
IKU2	H21	H22	...	H2j
IKU3	H31	H32	. . .	H3j
IKU4	H41	H42	...	H4j
IKU5	H51	H52	...	H5j
IKU6	H61	H62	. . .	H6j
IKU7	H71	H72	...	H7j
IKU8	H81	H82	...	H8j
Total Relationship	∑ Hi1	∑ Hi3	...	∑ Hij

Table 2: Modified House of Risk (HoR)

Risk Event (Ei)	Risk Agent (Aj)				(Si)
	A1	A2	. . .	Aj	
E1	R11	R12	. . .	R1j	S1
E2	R21	R22		R2j	S2
..	. . .	. . .	. . .	. . .	. . .
Ei	Ri1	Ri2	. . .	Rij	Si
Relationship value of business process to IKU (Pj)	P1	P2	. . .	Pj	
ARP j Rank of risk agent j	ARP1	ARP2	. . ..	ARPj	

Table 3: Relationship Matrix between Business Process and IKU

IKU (what)	Business Process (how)																			
	TE1	TE2	TE3	TE4	TE5	TE6	TE7	TE8	TE9	TE10	RC1	RC2	RC3	RC4	RC5	RC6	SA1	SA2	SA3	SP1
IKU1		3	9	3	3	9		9	3						1		9	9	9	
IKU2					1						3				3					
IKU3	9				9		9			3			3							
IKU4					1	1	3													
IKU5	9	3			1		3			1	9	9	9	3	3	9				
IKU6	9	3			3	1	3			1	1	1	1	3	3					
IKU7			3	9	1				1						3	1				
IKU8	9	3		1	1						3		1	3	3	1				9
Total Relation	36	12	12	13	20	11	18	9	4	5	16	10	14	9	16	11	9	9	9	9

3 CONCLUSSION

In this article, a modified HOR1 model has been implemented to identify risk agents and risk events business process pada HEI. Modification HOR1 is done by replacing the occurrence probability of risk agent (Oj) with total relationship value business process j with performance indicators (Pj). In the context of HEI, the use of Pj in calculating ARP is more appropriate because every business process planning always leads to the achievement of performance indicators. HOR1 can be implemented at HEIs to identify priorities for risk agent improvement in teaching, research & community services, student affairs, and supporting activities. In this case, most of the risk agent improvement priorities are related to research activities: lack of research ability, lack number of research and community services proposals, research group does not establish or inactive, and low research culture. The next research opportunity is to use the fuzzy method in assessing the relationship between the business process and IKU and the relationship between risk agents and risk events.

REFERENCES

[1] I. J. Mulyana, M. L. Singgih, and S. G. Partiwi, 'A Proposed of Lean Six Sigma Framework for Higher Education Institution (LSSF - for HEdu) To Improve Effectiveness and Efficiency of Higher Education in Indonesia', in *Proceedings of the Second Asia Pacific International Conference on Industrial Engineering and Operations Management*, 2021, pp. 481–493, http://ieomsociety.org/proceedings/2021indonesia/ 79.pdf.

[2] N. Wulandari and J. W. De Jager, 'Students ' Expectations of Higher Educational Experience in Public vs . Private Universities in Indonesia', *New Educ. Rev.*, 2018, doi: 10.15804/tner.2018.54.4.12.

[3] L. R. . Reavill, 'Quality assessment, total quality management and the stakeholders in the UK higher education system', *Manag. Serv. Qual. An Int. J.*, vol. 8, no. 1, pp. 55–63, 1998, doi: 10.1108/09604529810199395.

[4] M. A. C. Pereira and M. T. Da Silva, 'A key question for higher education: Who are the customers', in *Proceeding of the 31st Annual Conference of the Productions Management Society, POM-2003, April 4-7, 2003*, 2003, pp. 4–7, http://www.marco.eng.br/publicacoes/2002-POMS- A Key Question.PDF.

[5] H. B. Hwarng and C. Teo, 'Translating customers' voices into operations requirements: A QFD application in higher education', *Int. J. Qual. Reliab. Manag.*, vol. 18, no. 2, pp. 195–225, 2001, doi: 10.1108/02656710110379075.

[6] S. Sahney, 'Delighting customers of management education in India: A student perspective, part II', *TQM J.*, vol. 23, no. 5, pp. 531–548, 2011, doi: 10.1108/17542731111157635.

[7] S. Sahney, 'Delighting customers of management education in India: A student perspective, part I', *TQM J.*, vol. 23, no. 6, pp. 644–658, 2011, doi: 10.1108/17542731111175257.

[8] M. S. Owlia and E. M. Aspinwall, 'A framework for measuring quality in engineering education', *Total Qual. Manag.*, vol. 9, no. 6, pp. 501–518, Aug. 1998, doi: 10.1080/0954412988433.

[9] M. P. Mcdowall, 'Applying the Kano Model To Higher Education: Moving Beyond Measuring Student Satisfaction', University of North Dakota, 2016.

[10] G. C. M. Ku and I. W. Shang, 'Using the integrated kano–RIPA model to explore teaching quality of physical education programs in Taiwan', *Int. J. Environ. Res. Public Health*, vol. 17, no. 11, pp. 1–14, 2020, doi: 10.3390/ijerph17113954.

[11] R. Md. Sum and Z. M. Saad, 'Risk Management in Universities', in *3rd International Conference of Qalb-Guided Leadership in Higher Education Institutions 2017 (iQALB 2017)*, 2017, pp. 128–142,

[12] C. Dale, L. Goldstein, S. L. Johnson, J. A. Mattie, and J. Morley, James E., 'Developing a Strategy to Manage Enterprisewide Risk in Higher Education', 2001.

[13] R. Md. Sum, 'Risk Prioritisation (RP): A Decision Making Tool For Risk Management', Macquarie University, 2015.

[14] I. N. Pujawan and L. H. Geraldin, 'House of risk: a model for proactive supply chain risk management', vol. 15, no. 6, pp. 953–967, 2009, doi: 10.1108/14637150911003801.

[15] D. S. Dewi, B. Syairudin, and E. N. Nikmah, 'Risk Management in New Product Development Process for Fashion Industry: Case Study in Hijab Industry', *Procedia Manuf.*, vol. 4, no. Iess, pp. 383–391, 2015, doi: 10.1016/j.promfg.2015.11.054.

[16] C. Kasemset, J. Wannagoat, W. Wattanutchariya, and K. Y. Tippayawong, 'A risk management framework for new product development: A case study', *Ind. Eng. Manag. Syst.*, vol. 13, no. 2, pp. 203–209, 2014, doi: 10.7232/iems.2014.13.2.203.

[17] D. Isfianadewi, A. Pambudi, Y. Siswanti, J. Surjanti, and Muafi, 'Risk mitigation in design & production new product development process (case study: hijab company in yogyakarta)', *Int. J. Mech. Eng. Technol.*, vol. 9, no. 6, pp. 57–66, 2018.

[18] N. Hartono, A. Christiani, and T. Lasiman, 'Integrated model of service blueprint and house of risk (HOR) for service quality improvement', *IOP Conf. Ser. Earth Environ. Sci.*, vol. 195, no. 1, p. 012044, Dec. 2018, doi: 10.1088/1755-1315/195/1/012044.

[19] Z. Lazić, A. Đorđević, and A. Gazizulina, 'Improvement of quality of higher education institutions as a basis for improvement of quality of life', *Sustain.*, vol. 13, no. 8, 2021, doi: 10.3390/su13084149.

[20] *Buku Panduan Indikator Kinerja Utama Perguruan Tinggi Negeri*. Direktorat Jenderal Pendidikan Tinggi Kemdikbud RI, 2020.

APPENDIX 1. BUSINESS PROCESS, RISK EVENT AND RISK AGENT

Activity	Business Process	Code	Risk Event	Code	Risk Agent	Code
Teaching	Lecturer study doctoral degree	TE1	Few lecturers study doctoral degree	E1	Low motivation to study doctoral degree	A1
			Long time to finished doctoral degree	E2	Lack of research ability	A2
	Add and upgrade laboratory tools and equipment	TE2	Lack of laboratory tools and equipment or out of date	E3	Less laboratory budget	A3
	Curriculum structure supports IT analysis and literacy skills	TE3	Curriculum does not support IT analysis and literacy skills	E4	Inability of curriculum design	A4
	Use of appropriate teaching methods to subject	TE4	Lecturers use teaching methods that are not in accordance with subject	E5	Lecturers do not understand the appropriate teaching methods	A5
	Internship program for lecturers	TE5	Most lecturers are not internship	E6	University does not have good relations with industry	A6
	Industry Involvement in curriculum design	TE6	Few industries involvement in curriculum design	E7	University does not have good relations with industry	A6
	Training program for industry	TE7	There is no training program for the industry.	E8	The training materials offered are not as needed	A7
	Graduate's skills requirement survey	TE8	Low response rate from respondents	E9	Improper survey methods	A8
	Empathy training for lecturers	TE9	No/few lecturers participated in empathy training	E10	Lack of Interest of lecturers to join in empathy training	A9
	Professional Certification for lecturers	TE10	Few /no lecturers have expertise certification	E11	Lack of interest in certification	A10
					No related certification program	A11
Research & Community Services	Allocation of research and community services budgets	RC1	Low budget of research and community services	E12	Lack number of research and community services proposal	A12
					Research group does not establish or inactive	A13
	Mechanism of applying research and community services funds	RC2	The process of submitting research and community services budget is too long	E13	The mechanism of proposing fund is too complicated and take time	A14
	Training in writing research and community services proposals	RC3	Lack of participant in training of writing research and community services proposals	E14	Lack of interest in research and community services	A12
					Excess lecturer workload	A15
	International journal database subscription	RC4	Data base is rarely used	E15	Database is not as needed	A16
					Lack of interest in research and community services	A12
					Lecturers do not give assignments to students to find journals	A17
	Journal writing training for students and lecturers	RC5	The number of journals is still low.	E16	The interest of lecturers and students to write journals is still low	A18
					Research group does not establish or inactive	A13
	Development of research group	RC6	No research group or inactive	E17	Low research culture	A19
Student Affair	Career training for students	SA1	Little participants in career guidance	E18	Lack of student's attention to career guidance needs	A20
	Job fair and recruitment on campus	SA2	Less companies and students participating in the job fair	E19	The timing of the job fair is not right	A21
	Professional certification program for students	SA3	Lack of participant in professional certification	E20	Students do not yet aware to the importance of professional certification	A22
Supporting	Implementation of internal quality audit	SP1	Working unit late to collects internal audit documents	E21	Difficult to find supporting data	A23
					Lack of commitment and coordination in internal audit implementation	A24

APPENDIX 2. HOUSE OF RISK (HOR1)

Risk Event (Ei)	Risk Agent (Aj)																								(Si)
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	
E1	9	9																							10
E2	9	9																							5
E3			9																						5
E4				9																					5
E5					9																				8
E6						9																			4
E7						9																			7
E8			3			9	9																		3
E9						9		9																	5
E10									9																5
E11	3									9	9														6
E12	9	9										9	9												8
E13												9	3	9											5
E14	3											9	3	3	3				9						5
E15	9	3										3	3	3	3	9	9		3						3
E16	9	9										9	3	3	3	1		9	9						8
E17	9	9										3		1	1	1		3	9						5
E18																				9					3
E19						3														3	9				3
E20																						9			4
E21																							9	9	5
$\sum S_i R_{ij}$	384	333	54	45	72	180	27	45	45	54	54	258	135	98	53	40	27	87	171	36	27	36	45	45	
Relationship value of business process to IKU (Pj)	36	36	12	12	13	20	18	9	4	5	5	16	16	10	14	9	9	16	11	9	9	9	9	9	
Aggregate Risk Potential (ARPj)	13824	11988	648	540	936	3600	486	405	180	270	270	4128	2160	980	742	360	243	1392	1881	324	243	324	405	405	
Priority rank of risk agent j	1	2	11	12	9	4	13	14	24	20	20	3	5	8	10	17	22	7	6	18	22	18	14	14	

A Combined Application of SERVQUAL and fuzzy DEMATEL to Evaluate a University's Service Quality

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ABSTRACT

Owing to the rapid development of today's globalized era, studies on service quality improvement has been an increasing concern. The service sector, unlike goods, offers intangible products, and it is often difficult to evaluate. Several fundamental techniques were developed to address the issue such as service quality (SERVQUAL) and multi-criteria decision-making (MCDM). However, due to different system natures, the application is often limited to the specific sector such as education sector. Accordingly, this study aims to develop a decision-making model to determine key criteria and to visualize causal relationships among criteria in the education sector. A case study of student admission service in an Indonesian private university is selected. The service has an important role to attract prospective students choosing the university. The integration of SERVQUAL and fuzzy DEMATEL (decision making trial and evaluation laboratory) was selected since the SERVQUAL method is able to identify relevant service quality criteria, while fuzzy DEMATEL can visualize cause-and-effect relationships among criteria. In this study, nine criteria were identified. Then, the fuzzy DEMATEL method determined two key criteria, namely reliability and communication. Besides, two identity criteria were classified, which were: cause criteria group and effect criteria group. A digraph was developed to model the relationships for both cause and effect criteria group. This study may provide a significant implication for the decision-makers (DMs) in education sector when determining an improvement priority in a service system.

CCS CONCEPTS

• **Applied computing** → Operations research; Decision analysis; Multi-criterion optimization and decision-making; • **Social and professional topics** → Professional topics; Computing education.

*Place the footnote text for the author (if applicable) here.

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KEYWORDS

Education Sector, Service Quality, MCDM

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1 INTRODUCTION

In today's global economy, the service sector has become a promising sector [24]. In some developed countries, the sector can even contribute more than 75% of the gross domestic product, and accounts for about 83% of the total existing employment [2, 17]. As the service sector must be considered, the quality in this sector is often difficult to evaluate since it comprises intangible indicators which are closely related to the consumer's satisfaction [8]. A raising awareness by service providers can certainly be an added value as the providers may utilize the historical data to explore information, find hidden patterns, and formulate hypotheses in order to investigate the service deficiencies. A strong concern on service quality also helps the providers to be competitive, increasing company's profitability as well as market share [14, 17]. Accordingly, it is imperative for service providers to measure service quality by identifying consumers' wants and needs as well as their experience in order to increase loyalty and satisfaction [8, 12].

Higher education institutions providing education service globally, of course, also face their own challenges once there are increasing demands and expectations from consumers, in this case students [6, 19]. To ensure the quality offered, the decision-makers (DMs) in universities should be committed to implement continuous improvements as today's the global competition among universities has become tougher [4, 6, 16]. In this situation, several parties should be involved including students who are the most important party directly receiving the service [16]. Some of perceived service qualities include learning materials, administrative service, academic facilities, campus infrastructure, and other supporting services which affecting student loyalty [6]. Student loyalty is considered as a key indicator since it enables the DMs for determining right programs in building, promoting, developing, and ensuring

sustainable students – alumni relationships, and thus these are very influential for universities' future [1].

With regards to the topics of service quality in education sector, some past studies had addressed related issues with the service quality (SERVQUAL) method, multi-criteria decision-making (MCDM) techniques, and the fuzzy theory. The SERVQUAL method was the primary and the most popular method which became a basis to measure service quality. The method firstly presented by Parasuraman et al. in 1988 was utilized to measure the gap between consumers' perceptions due to service offered by a provider and their expectations [5, 18, 23, 25]. A clear example in education sector was presented by Đonlagić and Fazilć (2015). The study measured a service gap in a higher education institution (faculty of economics) in Bosnia dan Herzegovina [5]. Another SERVQUAL study by Soares et al. (2017) aimed at reporting the quality of administrative service focusing on students' perspective in a public university [22]. Galeeva (2016) proved that the SERVQUAL method could be applied to evaluate various university's services demonstrated in the Russian university [7]. Although the SERVQUAL method has been widely applied in service quality studies, the method may not able for solving complex decision-making problems. In this case, past studies applied the MCDM techniques to describe thorough results.

The DEMATEL method is an MCDM approach which has often been integrated with the SERVQUAL. As the method is able to visualize causal relationships among service dimensions, the combination between SERVQUAL and DEMATEL had been applied to improve service quality by investigating key factors in a particular system such as health services [9–11, 21]. However, an integrated SERVQUAL – DEMATEL approach developed in education sector is very limited. This study attempts to fill this gap. The purpose of this study is twofold: 1) to identify key service criteria applied in education service, and 2) to develop a causal relationship model. To achieve these objectives, a combination of SERVQUAL – DEMATEL is utilized. A fuzzy logic is also applied in order to achieve a more real relationship. In addition, a case study of student admission service in an Indonesian private university is selected. In a private university, student admission service has a key role to raise public trust and interest. The service should be the first impression which determine whether or not prospective students decide to choose a university. However, it is often that the DMs in most universities ignore some basic service indicators which emphasize that students must be treated as key customers. Therefore, it is obvious that DMs in a private university must improve the quality of the service continuously. This study may provide a service quality model describing causal relations among dimensions which is beneficial to make more effective quality improvements.

2 METHOD

Initially, the service criteria are defined based on the SERVQUAL dimensions. Then, the DMs are involved to give preference scores in criteria comparisons. In this study, the chief of student admission and the committee coordinator who are responsible for the service quality were invited. To bring a more detail analysis, the fuzzy DEMATEL method is utilized as this method is able to describe causal relations among criteria. A fuzzy environment is proposed to develop the DEMATEL to avoid ambiguities caused by experts' subjective judgments [15]. A fuzzy DEMATEL procedure follows Lin (2013) described below [15]:

Table 1: The fuzzy linguistic scale

Linguistic terms	Influence score	Triangular fuzzy numbers
No influence (NI)	0	(0.0, 0.1, 0.3)
Very low influence (VL)	1	(0.1, 0.3, 0.5)
Low influence (L)	2	(0.3, 0.5, 0.7)
High influence (H)	3	(0.5, 0.7, 0.9)
Very high influence (VH)	4	(0.7, 0.9, 1.0)

Step 1. Transforming the linguistic information obtained from criteria comparisons to the fuzzy linguistic scales as shown in table 1. By using eq. 1) – eq. 9), the TFNs are converted to crisp values. Since there were two experts involved, eq. 5) is taken to integrate the crisp values to obtain the DEMATEL initial direct relation matrix. Normalization

$$xa_{1ij}^{k} = \frac{\left(a_{1ij}^{k} - min\ a_{1ij}^{k}\right)}{\Delta_{min}^{max}} \tag{1}$$

$$xa_{2ij}^{k} = \frac{\left(a_{2ij}^{k} - min\ a_{2ij}^{k}\right)}{\Delta_{min}^{max}} \tag{2}$$

$$xa_{3ij}^{k} = \frac{\left(a_{3ij}^{k} - min\ a_{3ij}^{k}\right)}{\Delta_{min}^{max}} \tag{3}$$

$$\text{Where}\Delta_{min}^{max} = \max r_{ij}^{n} - \min l_{ij}^{n} \tag{4}$$

Compute right (rs) and left (ls) normalized values:

$$xls_{ij}^{k} = \frac{xa_{2ij}^{k}}{\left(1 + xa_{2ij}^{k} - xa_{1ij}^{k}\right)} \tag{5}$$

$$xrs_{ij}^{k} = \frac{xa_{3ij}^{k}}{\left(1 + xa_{3ij}^{k} - xa_{2ij}^{k}\right)} \tag{6}$$

Compute total normalized crisp values:

$$x_{ij}^{k} = \frac{\left[xls_{ij}^{k}\left(1 - xls_{ij}^{k}\right) + xrs_{ij}^{k} \times xrs_{ij}^{n}\right]}{\left(1 - xls_{ij}^{k} + xrs_{ij}^{k}\right)} \tag{7}$$

Compute crisp values:

$$\omega_{ij}^{-k} = \min a_{ij}^{n} + x_{ij}^{n}\Delta_{min}^{max} \tag{8}$$

Integrate crisp values from different opinions of k respondents:

$$\omega_{ij}^{-k} = \frac{1}{k\left(\omega_{ij}^{-1} + \omega_{ij}^{-2} + \ldots + \omega_{ij}^{-k}\right)} \tag{9}$$

Step 2. Once the initial direct-relation matrix A is obtained, with the DEMATEL procedure the normalized direct-relation matrix S can be calculated using eq. 10) where each element in the matrix ranges between 0 and 1.

$$S = k \times A \tag{10}$$

where

$$k = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \tag{11}$$

Step 3. Calculating the total-relation matrix T using eq. 12) in which I denotes the identity matrix.

$$T = S(I - S)^{-1} \tag{12}$$

Step 4. The last step is to compute the sum of rows (D) and the sum of columns (R) from the elements of matrix T using eq. 13) and (14), respectively. To visualize a digraph, a threshold value (α) is previously set up by calculating the average of the matrix T' elements. The threshold value indicates the significance of relationship from each dimension where the relationship is depicted in causal map. A digraph consists of two axes, namely the horizontal axis (D+R) dan the vertical axis (D-R). Positive values of the vertical axis indicate cause factors, otherwise the others are effect factors.

$$D = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = [t_i]_{n\times 1}, \quad i = 1, 2, \ldots, n \tag{13}$$

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = \left[t_j\right]_{1\times n}, \quad j = 1, 2, \ldots, n \tag{14}$$

3 RESULTS AND DISCUSSION

3.1 The identification of service criteria based on the SERVQUAL dimensions

There were nine criteria identified based on the SERVQUAL dimensions. To determine the nine criteria, a literature review was first conducted referring to [3, 13, 20]. These criteria were also confirmed by the DMs in the university. These nine criteria were reliability (C_1), responsiveness (C_2), competence (C_3), access (C_4), courtesy (C_5), communication (C_6), credibility (C_7), security (C_8), and tangibles (C_9). The reliability criterion (C_1) includes punctuality, conformity with procedures, and uniformity of information delivered. The responsiveness criterion (C_2) indicates a fast and right quality response. The competence criterion (C_3) includes knowledge, skill, and attitude possessed by the service staffs. The access criterion (C_4) indicates accessible service and the information that easy to find. The courtesy criterion (C_5) indicates a friendliness aspect and respect given by the staffs when providing services. The communication criterion (C_6) indicates communication skills. The credibility criterion (C_7) indicates valid and reliable information provided. The security criterion (C_8) includes the security of service area as well as the confidentiality of information given, and the last is the tangibles criterion (C_9) indicates staffs' appearances, display of service area, and promotional materials offered.

3.2 The construction of the initial direct-relation matrix

The second step is to construct the initial direct-relation matrix A. To obtain the matrix, the DMs were initially interviewed to provide influence relationships between the two criteria with a scale of 0 to 4. As shown in table 1, the scales indicate influence scores describing no influence (NI), very low influence (VL), low influence (LI), high influence (HI), and very high influence (VH), respectively.

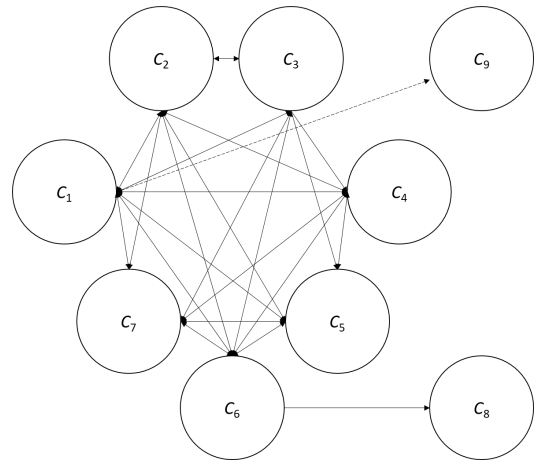

Figure 1: The causal map

Since two experts were involved in this step, there were two direct-relation matrices as presented in table 2 dan table 3. These matrices were then transformed into TFNs based on the rule as indicated in table 1. Table 4 shows an example of a TFN's matrix from expert 1 (the chief of student admission). To obtain the initial direct-relation matrix A, the eq. 1) - eq. 9) were applied. The matrix as shown in table 5 contains crisp set integrated from different opinions of two experts.

3.3 The visualization of cause-and-effect relationships by the digraph

To develop a digraph, the total-relation matrix T as shown in table 6 is constructed using eq. 12). Before, the normalized direct-relation matrix S is computed using eq. 10) in which the initial direct-relation matrix A is an input.

The total-relation matrix provides key elements to develop a digraph. The D and R elements of matrix T generate axis values. Since a digraph consists of two axes which are the horizontal axis indicating "prominence" and the vertical axis indicating "relation", the addition of D and R is plotted based on horizontal points, while the subtraction of D and R is plotted based on vertical points. Table 7 provides information of horizontal axis, vertical axis, and identity for each criterion.

As shown in table 7, the "cause" criteria and "effect" criteria comprise of four criteria (C_2, C_3, C_5, C_6) and five criteria (C_1, C_4, C_7, C_8, C_9), respectively. The identity criteria are classified based on the values from the vertical "relation" axis. The positive value indicates cause criterion, otherwise the negative is effect criterion. The identity criteria reveal that the cause criteria may have significant influences to the effect criteria. The causal relations among criteria clearly illustrated in figure 1 and figure 2 below.

The causal map presents interactions between criteria based on the threshold value (α) of 0.701. The threshold value determines the significance of relations obtained from the elements' values in the matrix T. Once the values are greater than the threshold value, they are considered bring significant influences. Figure 1 is illustrated to ease the DMs when understanding the relationships between

Table 2: Direct-relation matrix from expert 1

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	NI	VH	VH	H	H	VH	H	H	VH
C_2	VH	NI	VH	VH	VH	VH	VH	H	H
C_3	VH	H	NI	H	H	VH	VH	L	H
C_4	H	VH	H	NI	H	H	H	H	L
C_5	VH	VH	L	H	NI	VH	H	H	VH
C_6	VH	VH	VH	H	VH	NI	VH	VH	H
C_7	VH	H	L	VH	H	H	NI	VH	H
C_8	VH	H	L	H	L	L	VH	NI	L
C_9	L	VL	H	L	VL	VL	L	H	NI

Table 3: Direct-relation matrix from expert 2

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	NI	VH	VH	VH	VH	VH	VH	L	VH
C_2	VH	NI	VH	VH	VH	VH	H	L	L
C_3	H	H	NI	VH	VH	H	VH	VH	VL
C_4	H	H	VH	NI	VH	VH	H	L	VL
C_5	VH	VH	L	VH	NI	VH	VH	VL	VH
C_6	VH	VH	H	VH	VH	NI	VH	VH	H
C_7	VH	VH	H	VH	H	VH	NI	VH	VL
C_8	H	L	VL	H	H	VH	VH	NI	VL
C_9	VH	H	L	VH	VH	H	L	VL	NI

Table 4: An example of the TFN's transformation from expert 1

	C_1	C_2	C_3	C_4-C_6	C_7	C_8	C_9
C_1	1.0,	0.7,	0.7,	...	0.5,	0.5,	0.7,
	1.0,	0.9,	0.9,		0.7,	0.7,	0.9,
	1.0	1.0	1.0		0.9	0.9	1.0
C_2	0.7,	1.0,	0.7,	...	0.7,	0.5,	0.5,
	0.9,	1.0,	0.9,		0.9,	0.7,	0.7,
	1.0	1.0	1.0		1.0	0.9	0.9
C_3	0.7,	0.5,	1.0,	...	0.7,	0.3,	0.5,
	0.9,	0.7,	1.0,		0.9,	0.5,	0.7,
	1.0	0.9	1.0		1.0	0.7	0.9
C_4-C_6	...	...	...	...	...	...	...
C_7	0.7,	0.5,	0.3,	...	1.0,	0.7,	0.5,
	0.9,	0.7,	0.5,		1.0,	0.9,	0.7,
	1.0	0.9	0.7		1.0	1.0	0.9
C_8	0.7,	0.5,	0.3,	...	0.7,	1.0,	0.3,
	0.9,	0.7,	0.5,		0.9,	1.0,	0.5,
	1.0	0.9	0.7		1.0	1.0	0.7
C_9	0.3,	0.1,	0.5,	...	0.3,	0.5,	1.0,
	0.5,	0.3,	0.7,		0.5,	0.7,	1.0,
	0.7	0.5	0.9		0.7	0.9	1.0

cause-and-effect relations previously plotted in the digraph. It can be clearly seen that those nine criteria are influencing each other. For instance, the communication criterion (C_6) classified as cause

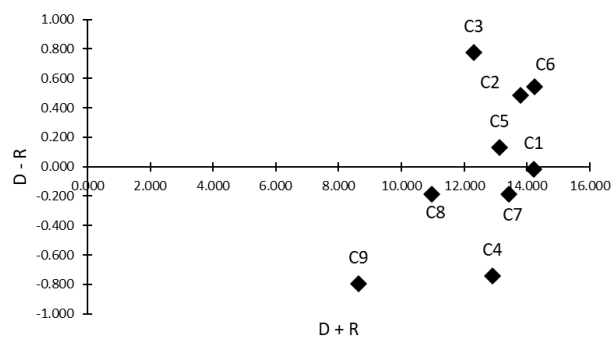

Figure 2: The causal diagram

criteria group bring significant effects on reliability, responsiveness, competence, access, courtesy, credibility, and security. This criterion is the most influential criterion where the influence score from C_1 to C_8 are 0.918, 0.867, 0.750, 0.869, 0.849, 0.893, 0.883, and 0.774, respectively. Besides, the C_8 criterion seems to be only influenced by the C_6 criterion. This may describe that the consumer's trust in giving information can be achieved through a good and clear communication.

Despite the criteria's reciprocating relations, the tangibles criterion, interestingly, can actually be supposed to be an independent criterion. The dotted lines seen in the causal map actually indicates

Table 5: The initial direct-relation matrix *A* from *k* experts

	C_1	C_2	C_3	C_4-C_6	C_7	C_8	C_9
C_1	0.693	0.674	0.674	...	0.587	0.400	0.674
C_2	0.676	0.731	0.674	...	0.587	0.400	0.400
C_3	0.587	0.500	0.731	...	0.673	0.488	0.300
C_4 - C_6	...	...	...	...	...	...	...
C_7	0.676	0.587	0.400	...	0.720	0.674	0.300
C_8	0.587	0.400	0.200	...	0.673	0.731	0.200
C_9	0.489	0.300	0.300	...	0.300	0.300	0.410

Table 6: Total relation matrix *T*

	C_1	C_2	C_3	C_4-C_6	C_7	C_8	C_9
C_1	0.889	0.837	0.743	...	0.836	0.669	0.628
C_2	0.892	0.855	0.749	...	0.842	0.673	0.583
C_3	0.811	0.751	0.704	...	0.797	0.641	0.520
C_4 - C_6	...	...	...	...	...	...	...
C_7	0.835	0.774	0.650	...	0.812	0.681	0.525
C_8	0.686	0.616	0.504	...	0.677	0.588	0.419
C_9	0.508	0.448	0.396	...	0.456	0.382	0.352

Table 7: The information of prominence and relation

	C_1	C_2	C_3	C_4-C_6	C_7	C_8	C_9
D	7.10	7.15	6.54	...	6.62	5.39	3.91
R	7.12	6.67	5.77	...	6.80	5.57	4.71
D+R	14.23	13.8	12.31	...	13.42	10.96	8.63
D-R	-0.08	0.49	0.78	...	-0.19	-0.18	-0.79

a vague relation since none of these criteria has a significant value which is greater than 0.701 towards the C_9 criterion. It is suggested that the DMs in the organization can enhance the tangible aspects in the service without considering the impact of the other criteria. However, as clearly seen in the causal map that the tangible criterion is connected – by a dotted line – with the reliability criterion since the reliability has the most significant influence of 0.628 among the others to bring effect on the criterion.

In this study, the causal map and the digraph may not only provide causal relations among criteria, but also assist the DMs in identifying the key criteria. From the vertical axis, the C_3 criterion hit the highest vertical scores of 12.311 which indicates the most dominant "cause" criterion, and thus this criterion should be considered. In addition, by dividing the elements of (*D+R*) for each criterion by the sum of (*D+R*) for all criteria, the weights of criteria can be obtained. The result indicated that the nine criteria have respective weights of 0.125 for C_1, 0.122 for C_2, 0.108 for C_3, 0.114 for C_4, 0.116 for C_5, 0.125 for C_6, 0.118 for C_7, 0.096 for C_8, and 0.076 for C_9. Based on the result, the criteria order from the highest to the lowest is $C_1(C_6)>C_2>C_7>C_5>C_4>C_3>C_8>C_9$. Both C_1 and C_6 can be considered as key criteria as these two criteria have the highest weight and have the most significant influence to the other criteria. Hence, it is presented that the fuzzy DEMATEL provides a decision-making tool for improving a service system once a strategic decision is made especially taking into account limited resources.

4 CONCLUSION

To evaluate service quality, the dimensions listed in SERVQUAL are very relevant to be applied to various service systems. In this study, the SERVQUAL dimensions were adopted to evaluate service quality in education sector demonstrated in student admission service. With a literature study and expert group discussion, there were nine criteria identified, which were: reliability, responsiveness, competence, access, courtesy, communication, credibility, security, dan tangibles. Then, the fuzzy DEMATEL method was utilized to model the criteria' interactions. Further, a fuzzy logic developed into DEMATEL has a good capacity since avoiding ambiguities in

order to visualize real relationships. A real relation, for instance, was indicated that the DMs can focus on the tangible criterion without considering the others. In addition, this study has identified key criteria, namely C_1 and C_6. These two dimensions are suggested to be prioritized when improving the overall service system. Hence, this paper provides a significant contribution, especially for decision-making process in the education service. For further development, it is encouraged to take into account improvement strategies addressing the service quality issues. With regards to the quantitative method, the hierarchical-based MCDM method (example: ANP) can be utilized to produce more reliable weights as the method aims to specifically obtain criteria weights based on the interaction structure.

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REFERENCES

[1] Subrahmanyam Annamdevula and Raja Shekhar Bellamkonda. 2016. The effects of service quality on student loyalty: the mediating role of student satisfaction. *Journal of Modelling in Management* 11, 2 (2016), 446–462. DOI:https://doi.org/10.1108/JM2-04-2014-0031

[2] Uday Apte, Costis Maglaras, and Michael Pinedo. 2008. Operations in the service industries: Introduction to the special issue. *Production and Operations Management* 17, 3 (May 2008), 235–237. DOI:https://doi.org/10.3401/poms.1080.0032

[3] Zehra Bozbay, Fakhri Baghirov, Ye Zhang, Amran Rasli, and Meltem Karakasoglu. 2020. International students' service quality evaluations towards Turkish universities. *Quality Assurance in Education* 28, 3 (July 2020), 151–164. DOI:https://doi.org/10.1108/QAE-06-2019-0061

[4] Ana Brochado. 2009. Comparing alternative instruments to measure service quality in higher education. *Quality Assurance in Education* 17, 2 (April 2009), 174–190. DOI:https://doi.org/10.1108/09684880910951381

[5] S Đonlagić and S Fazlić. 2015. *QUALITY ASSESSMENT IN HIGHER EDUCATION USING THE SERVQUAL MODEL assessment in higher education using the SERVQUAL model 40*. Quality. Retrieved from http://www.ehea.info/article-details.aspx?ArticleId=86

[6] Djafri Fares, Meguellati Achour, and Omar Kachkar. 2013. The Impact of Service Quality, Student Satisfaction, and University Reputation on Student Loyalty: A Case Study of International Students in IIUM, Malaysia.

[7] Railya B. Galeeva. 2016. SERVQUAL application and adaptation for educational service quality assessments in Russian higher education. *Quality Assurance in Education* 24, 3 (2016), 329–348. DOI:https://doi.org/10.1108/QAE-06-2015-0024

[8] Ali Ramezani Ghotbabadi, Setareh Feiz, and Rohaizat Baharun. 2015. Service Quality Measurements: A Review. *International Journal of Academic Research in Business and Social Sciences* 5, 2 (February 2015). DOI:https://doi.org/10.6007/ijarbss/v5-i2/1484

[9] Muhammet Gül, Ali Fuat Güneri, and Burcu Derin. EVALUATION OF SERVICE QUALITY CRITERIA FOR A PRIVATE MEDICAL CENTER BY USING SERVQUAL AND DEMATEL METHODS.

[10] Nahid Hatam, Ahmad Sadeghi, Payam Shojaee, Hasan Jafari, and Azimeh Ghorbanian. 2020. Effective factors on improving the quality of hospital services in south of Iran. *J Pak Med Assoc* 70, 10 (October 2020), 1709–1713. DOI:https://doi.org/10.47391/JPMA.865

[11] Songhe Jin, Shenyi Qian, and Huidong Zhu. 2013. IDENTIFYING KEY FACTORS OF PATIENT SATISFACTION BASED ON SERVQUAL AND DEMATEL. *J Theor Appl Inf Technol* 48, 2 (2013). Retrieved from www.jatit.org

[12] Tariq Khalil Bharwana, Mohsin Bashir, and Muhammad Mohsin. 2013. Impact of Service Quality on Customers' Satisfaction: A Study from Service Sector especially Private Colleges of Faisalabad, Punjab, Pakistan. *International Journal of Scientific and Research Publications* 3, 5 (2013). Retrieved from www.ijsrp.org

[13] Krisana Kitcharoen. THE IMPORTANCE-PERFORMANCE ANALYSIS OF SERVICE QUALITY IN ADMINISTRATIVE DEPARTMENTS OF PRIVATE UNIVERSITIES IN THAILAND **.

[14] Dapeng Liang, Zhenzhong Ma, and Liyun Qi. 2013. Service quality and customer switching behavior in China's mobile phone service sector. *Journal of Business Research* 66, 8 (August 2013), 1161–1167. DOI:https://doi.org/10.1016/j.jbusres.2012.03.012

[15] Ru Jen Lin. 2013. Using fuzzy DEMATEL to evaluate the green supply chain management practices. *Journal of Cleaner Production* 40, (February 2013), 32–39. DOI:https://doi.org/10.1016/j.jclepro.2011.06.010

[16] Frederic Marimon, Marta Mas-Machuca, Jasmina Berbegal-Mirabent, and Josep Llach. 2019. UnivQual: a holistic scale to assess student perceptions of service quality at universities. *Total Quality Management and Business Excellence* 30, 1–2 (January 2019), 184–200. DOI:https://doi.org/10.1080/14783363.2017.1302795

[17] Irena Ograjenšek. 2002. Applying Statistical Tools to Improve Quality in the Service Sector. FDV.

[18] Anita Quinn, Gina Lemay, Peter Larsen, and Dana M. Johnson. 2009. Service quality in higher education. *Total Quality Management and Business Excellence* 20, 2 (2009), 139–152. DOI:https://doi.org/10.1080/14783360802622805

[19] Moshe Sharabi. 2013. Managing and improving service quality in higher education. *International Journal of Quality and Service Sciences* 5, 3 (September 2013), 309–320. DOI:https://doi.org/10.1108/IJQSS-03-2013-0016

[20] Ahmadreza Shekarchizadeh, Amran Rasli, and Huam Hon-Tat. 2011. SERVQUAL in Malaysian universities: Perspectives of international students. *Business Process Management Journal* 17, 1 (February 2011), 67–81. DOI:https://doi.org/10.1108/14637151111105580

[21] Jiunn I. Shieh, Hsin Hung Wu, and Kuan Kai Huang. 2010. A DEMATEL method in identifying key success factors of hospital service quality. *Knowledge-Based Systems* 23, 3 (April 2010), 277–282. DOI:https://doi.org/10.1016/j.knosys.2010.01.013

[22] Mauri Cesar Soares, Olívio Novaski, and Rosley Anholon. 2017. SERVQUAL model applied to higher education public administrative services. *Brazilian Journal of Operations & Production Management* 14, 3 (September 2017), 338–349. DOI:https://doi.org/10.14488/bjopm.2017.v14.n3.a7

[23] Kay C. Tan and Sei W. Kek. 2004. Service quality in higher education using an enhanced SERVQUAL approach. *Quality in Higher Education* 10, 1 (2004), 17–24. DOI:https://doi.org/10.1080/1353832242000195032

[24] Yiting Xing, Ling Li, Zhuming Bi, Marzena Wilamowska-Korsak, and Li Zhang. 2013. Operations Research (OR) in Service Industries: A Comprehensive Review. *Systems Research and Behavioral Science* 30, 3 (May 2013), 300–353. DOI:https://doi.org/10.1002/sres.2185

[25] Khanchitpol Yousapronpaiboon. 2014. SERVQUAL: Measuring Higher Education Service Quality in Thailand. *Procedia - Social and Behavioral Sciences* 116, (February 2014), 1088–1095. DOI:https://doi.org/10.1016/j.sbspro.2014.01.350

Prior and Future Research on Quality-Driven Product Service Systems: A Literature Review

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ABSTRACT

The role of services in manufacturing is increasing. Service becomes a value addition to the products offered. A product-service system (PSS) is a tangible manifestation of the integration of services and products. However, the integration of products and services must still ensure the quality of PSS. This paper aims to review the development of research related to the quality of PSS where products and services are considered as an integral part of the integration results. Previous research investigations were carried out by collecting journals discussing PSS. The quality of PSS was then discussed, and its mapping to the quality dimension. The mapping shows the research clusters that can be examined for emerging trends in research and potential future research. Those potential future researches are related to the dimension of reliability, durability, serviceability, aesthetic, and perceived quality.

CCS CONCEPTS

• **General and reference** → Document types; General literature.

KEYWORDS

The quality of PSS, PSS future research, literature review

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1 INTRODUCTION

Along with the increasing trend of servitization, The Product-Service System (PSS) also experienced a proportional increase. During the last thirty years, Servitization and The Product-Service System (PSS) have become interesting topics to be developed [1]. Manufacturing businesses have a tendency to integrate services into the tangible goods, a practice known as servitization [2]. The Product-Service System (PSS) is how this integration actually manifests itself [3]. In general, PSS can be defined as an integrated system of products, services, support networks, and infrastructure designed to meet customer needs, increase competitiveness, and have a lower environmental impact than traditional business models [4]. Based on this definition, PSS consists of product and service aspects. The dominance of product and service integration will shape the category and character of PSS. Individually, products and services have different characteristics. If these two aspects are integrated, there will be interactions that can influence the development of innovation between the two [5].

Therefore, managing PSS throughout its life cycle will be a challenge for the company. Companies will also face challenges in the case of having to control the quality of products and services simultaneously. The existence of integration between products and services often causes vague boundaries between product and service itself [6]. Consequently, quality control policies on product and service integration are becoming more complex. However, company must ensure the quality of PSS. The goal of this paper is to look at how research on the quality of PSS has changed over time, where products and services are seen as an important part of the integration results.

2 METHODOLOGY

Based on the background that has been described, previous research investigations were carried out by collecting journals discussing PSS. Additionally, journal filtering is conducted. Thirty journals addressing PSS quality were identified from the filtered results. Understanding each journal's contribution to the growth of PSS quality research, the journals have been mapped into eight quality aspects. There are eight quality dimensions used for the journal mapping process, namely performance, features, reliability, conformance, durability, serviceability, aesthetic and perceived quality [7]. Garvin, (1996) states that a product or service may score highly on one aspect of quality while scoring poorly on another, because one aspect of quality may be improved at the expense of another. This quality dimension is also used for service quality dimensions [8] and products [9]. With the addition of time to the research mapping, it becomes easier to see how past research has changed over time. Furthermore, journal clustering is carried out based on the topics discussed. This journal cluster can be used to see in detail research topics related to the quality dimension

3 LITERATURE REVIEW

PSS as a manifestation of servitization can be a new strategy in business innovation. Service involvement in manufacturing provides a

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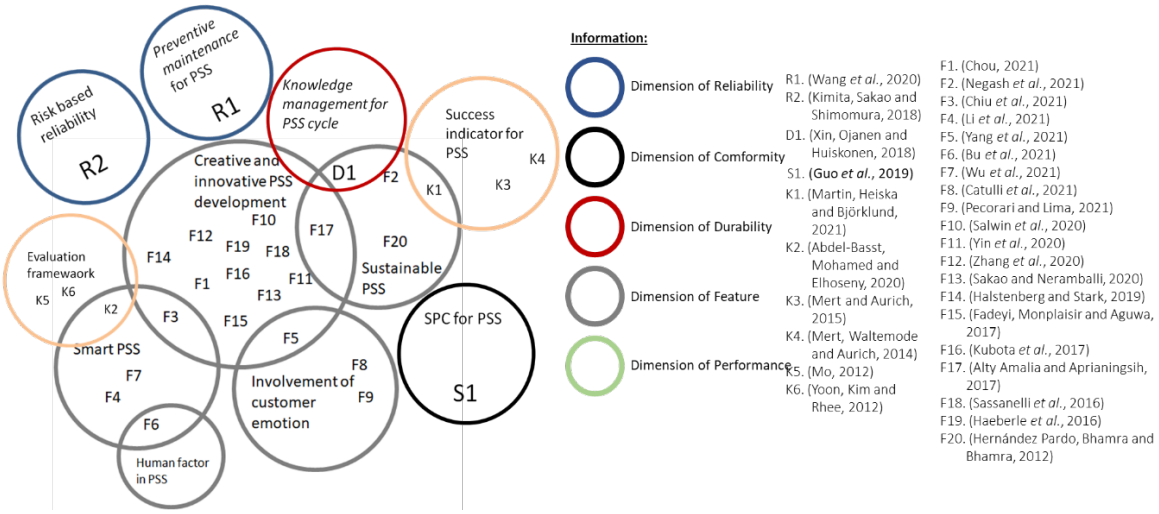

Figure 1: Previous Research Mapping ([22]; [23]; [24]; [25]; [26]; [27]; [28]; [29]; [30]; [31]; [13]; [32]; [12]; [10]; [33]; [20]; [21]; [34]; [35]; [36]; [37]; [16]; [17]; [14]; [15], [38], [18]; [19]; [39])

new package of offerings to customers in which the integration of products with services is inseparable [10]. The second definition of PSS that is widely used in the literature is the marketable set of products and services that are able to meet the user's needs [4]. The integration of products and services also changes how companies guarantee the quality of their products and services stays high. Customers also always want qualified PSS. Therefore, a literature review on the development of PSS research related to quality needs to be done. This is an effort by the company to follow business developments based on the development of customer taste.

Previous research reviews were carried out by reviewing relevant journals and clustering based on quality dimensions. The final goal of this paper is to find future research opportunities based on clusters of past research. Clustering of previous research can be done based on 8 dimensions of quality for products or services initiated by Garvin (1996). The results of the clustering of thirty journals are as Figure 1. On the feature dimension, there are 20 studies about PSS quality that can be grouped into 5 research topics: creative and innovative PSS development, sustainable PSS, customer emotional involvement, taking human factors into account in PSS, and smart PSS.

The densest cluster discusses how to develop PSS in unique ways, such as design by involving technology [11], personalization [12], and by using the TRIZ method, which emphasizes innovation [13]. PSS design can also be done by conducting system modeling [14, 15], optimization [16], and the use of big data [17]. From this cluster, it was found that the design of service integration with products should be carried out as early as possible in the early stages of design [18] and the selection of service parameters should be carried out systematically on existing product design methods [19].

The next cluster in this dimension is smart PSS, which involves technology features. This cluster has a wedge with the creative and innovative PSS development cluster. These slices are research that discusses the development of smart PSS by personalizing [12] and research that discusses human factors in PSS [20]. Other research on smart PSS clusters is the development of smart PSS by considering cyber-physical resources [11], and optimizing smart PSS with function orientation [21].

The next two clusters are the sustainable PSS and the customer's emotional involvement in the PSS. Negash et al. (2021) developed a sustainable PSS, taking into account the uncertainties in the pharmaceutical industry. Meanwhile, two other studies in the sustainable PSS cluster discuss the design of PSS for small and medium enterprises [39], such as in herbal medicine companies [38]. Meanwhile, research to explore emotional needs was carried out by Catulli et al. (2021) through a social experiment; Pecorari & Lima, (2021) through testing the relationship between experience and customer acceptance; and Yang et al., (2021) through exploring emotional needs on smart PSS. The next dimension is performance, which consists of two clusters, namely PSS success indicator and evaluation framework. Research on the PSS success indicator cluster discusses the evaluation of PSS by capturing several success measures, such as the environmental impact indicators provided [26], key performance indicators of the PSS development project [28], and quality measures of the PSS development project. PSS [29]. Research on the evaluation framework cluster provides a management for evaluating PSS, such as a framework for evaluating innovation value propositions (IVP) on smart PSS [27], a framework for engineering PSS using complex engineering products and service systems [30], and a framework for designing new PSS [31].

The next dimension is reliability, which consists of two studies. The first study is related to efforts to create a reliable PSS through failure analysis [23]. The second study is related to preventive maintenance for PSS [22]. In this study, there will be an adjustment of the method for the service aspect and its integration with the product aspect.

Table 1: Summary Information of Research Mapping

No	Dimension of Quality	Research Topic	Amount	Implication
1	**Reliability**	Risk based reliability	1	High opportunity to be investigated
		Preventive maintenance for PSS	1	High opportunity to be investigated
2	Conformity	Statistical Process Control for PSS	1	High opportunity to be investigated
3	Durability	Knowledge management for PSS cycle	1	High opportunity to be investigated
4	**Feature**	Creative and innovative PSS development	13	Variative research topic but congestion
		Sustainable PSS	2	Trending research concern
		Involvement of customer emotion	2	Trending research concern
		Human factor in PSS	1	Trending research concern
		Smart PSS	2	Trending research concern
5	**Performance**	Evaluation framework	3	Expanded research area for PSS
		Success indicator for PSS	3	Expanded research area for PSS
6	Aesthetic	-	-	Explorable new research area for PSS
7	Service-ability	-	-	Explorable new research area for PSS
8	Perceived quality	-	-	Explorable new research area for PSS

Another quality dimension is durability and suitability. This dimension gets the smallest percentage value. A study on the durability dimension discusses the application of knowledge management in the entire PSS life cycle [24]. Meanwhile, a study on the dimensions of conformity was carried out by Guo et al. (2019), who used turtle diagrams to analyze discrepancies that occurred in PSS, both in product and service aspects. If there is a discrepancy, it can be said that the PSS that has been designed is of poor quality and must be repaired immediately to make it better. When viewed from the year of research, this research is still relatively new. Thus, it can be said that the development of research for the dimension of suitability is still relatively slow.

4 RESULT AND DISCUSSION

Each quality dimension has a different focus. As a result, these variations become reason why research on each of its dimensions has developed differently. While each dimension has an impactful role in the running of the company. This mapping will be useful to know the development of research from time to time for each dimension. Furthermore, research opportunities can be identified to complement slow research progress. This previous research mapping can also be used to evaluate research equity on the topic of PSS quality. Tabular 1 provides a summary of the information that can be acquired from Figure 1.

Deployed research on the topic of PSS quality will be needed for the availability of references that can support the development of PSS itself. Thus, it is important to do a literature review to see the development of research on PSS quality. The results of adding the time variable to journal mapping are presented in Figure 2.

The intensity of the research is seen in the dimensions of the features, so that information can be obtained that research related to how to design or develop PSS to obtain appropriate features develops from time to time, with an increasing trend in 2021. Based on the 30 journals reviewed, it is also seen that research on PSS reliability only appeared in 2018 and another study reappeared in 2020. This shows the lack of research that wants to be conducted on PSS reliability. This dimension shows a very sharp decrease in

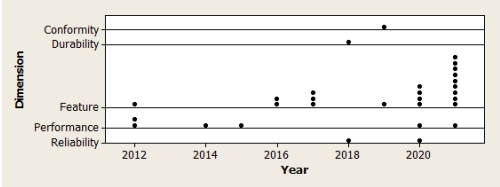

Figure 2: Timeline of previous research

the number of studies compared to the features and performance dimensions. This can be used as a good research opportunity to be developed. There are many research areas in the reliability of PSS that have not been discussed. Previous studies can be used as stepping stones for further research. Some of the things that can be studied are the reliability of PSS and the preventive maintenance efforts for some PSS characters.

Research developments in the dimensions of conformity and durability have the same character. Of the 30 journals reviewed, there was only one study dating to 2018. This shows that research on the topic of durability for PSS is a rare topic with slow research progress. It is clear that studies about the durability of PSS only began to be published in 2018, and until now there has still been no research that discusses the durability of PSS. Existing research on topics like the role of knowledge management in making PSS last longer and how to control PSS conformity can lead to new research ideas in this area. Other research opportunities can also be carried out on the dimensions of serviceability, aesthetics, and perceived quality. Based on the mapping of 30 previous studies that have not been seen, research related to PSS that discusses serviceability, aesthetics, and perceived quality.

5 CONCLUSION

Based on the literature review and mapping of previous PSS quality research, it can be concluded that PSS quality research is dominated by the feature dimension, which means a lot of research on how to design and develop PSS so that it can be accepted by customers.

In addition, the slow development of research is shown in the dimensions of reliability, durability, serviceability, aesthetics, and perceived quality. Thus, future research can be focused on these dimensions.

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REFERENCES

[1] Abdel-Basst, M., Mohamed, R. and Elhoseny, M. 2020. A novel framework to evaluate innovation value proposition for smart product–service systems. Environmental Technology and Innovation. 20, (Nov. 2020). DOI:https://doi.org/10.1016/j.eti.2020.101036.

[2] Alty Amalia, F. and Aprianingsih, A. 2017. Business Model of Jamu as Indonesian Traditional Herbal Medicine in New Economy. The Asian Journal of Technology Management. 10, 1 (2017), 19–28. DOI:https://doi.org/10.12695/ajtm.2017.10.1.3.

[3] Annarelli, A., Battistella, C., Costantino, F., di Gravio, G., Nonino, F. and Patriarca, R. 2021. New trends in product service system and servitization research: A conceptual structure emerging from three decades of literature. CIRP Journal of Manufacturing Science and Technology. Elsevier Ltd.

[4] Bu, L., Chen, C.H., Ng, K.K.H., Zheng, P., Dong, G. and Liu, H. 2021. A user-centric design approach for smart product-service systems using virtual reality: A case study. Journal of Cleaner Production. 280, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.124413.

[5] Catulli, M., Sopjani, L., Reed, N., Tzilivakis, J. and Green, A. 2021. A socio-technical experiment with a resource efficient product service system. Resources, Conservation and Recycling. 166, (Mar. 2021). DOI:https://doi.org/10.1016/j.resconrec.2020.105364.

[6] Chiu, M.C., Huang, J.H., Gupta, S. and Akman, G. 2021. Developing a personalized recommendation system in a smart product service system based on unsupervised learning model. Computers in Industry. 128, (2021), 103421. DOI:https://doi.org/10.1016/j.compind.2021.103421.

[7] Chou, J.R. 2021. A TRIZ-based product-service design approach for developing innovative products. Computers and Industrial Engineering. 161, 1 (2021), 107608. DOI:https://doi.org/10.1016/j.cie.2021.107608.

[8] Fadeyi, J.A., Monplaisir, L. and Aguwa, C. 2017. The integration of core cleaning and product serviceability into product modularization for the creation of an improved remanufacturing-product service system. Journal of Cleaner Production. Elsevier Ltd.

[9] Garvin, D.A. 1996. Competing on the eight dimensions of quality. IEEE Engineering Management Review. 24, 1 (1996), 15–23.

[10] Guo, H., Zhang, R., Chen, X., Zou, Z., Qu, T., Huang, G., Shi, J., Chen, M., Gu, H., Lun, Y., Li, J. and He, Z. 2019. Quality control in production process of product-service system: A method based on turtle diagram and evaluation model. Procedia CIRP (2019), 389–393.

[11] Haase, R.P., Pigosso, D.C.A. and McAloone, T.C. 2017. Product/Service-System Origins and Trajectories: A Systematic Literature Review of PSS Definitions and their Characteristics. Procedia CIRP. 64, (2017), 157–162. DOI:https://doi.org/10.1016/j.procir.2017.03.053.

[12] Haeberle, D., Imran, S., van Husen, C. and Droll, C. 2016. A New Approach for the Development of Services for Industrial Product-Service Systems. Procedia CIRP (2016), 353–357.

[13] Halstenberg, F.A. and Stark, R. 2019. Study on the feasibility of modelling notations for integrated product-service systems engineering. Procedia CIRP (2019), 157–162.

[14] Hernández Pardo, R.J., Bhamra, T. and Bhamra, R. 2012. Sustainable product service systems in Small and Medium Enterprises (SMEs): Opportunities in the leather manufacturing industry. Sustainability. 4, 2 (2012), 175–192. DOI:https://doi.org/10.3390/su4020175.

[15] Kimita, K., Sakao, T. and Shimomura, Y. 2018. A failure analysis method for designing highly reliable product-service systems. Research in Engineering Design. 29, 2 (Apr. 2018), 143–160. DOI:https://doi.org/10.1007/s00163-017-0261-8.

[16] Li, X., Lyu, M., Wang, Z., Chen, C.H. and Zheng, P. 2021. Exploiting knowledge graphs in industrial products and services: A survey of key aspects, challenges, and future perspectives. Computers in Industry. 129, (2021), 103449. DOI:https://doi.org/10.1016/j.compind.2021.103449.

[17] Li, X., Wang, Z., Chen, C.H. and Zheng, P. 2021. A data-driven reversible framework for achieving Sustainable Smart product-service systems. Journal of Cleaner Production. 279, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.123618.

[18] Mahut, F., Daaboul, J., Bricogne, M. and Eynard, B. 2015. Survey on product-service system applications in the automotive industry. IFAC-PapersOnLine. 28, 3 (2015), 840–847. DOI:https://doi.org/10.1016/j.ifacol.2015.06.188.

[19] Martin, M., Heiska, M. and Björklund, A. 2021. Environmental assessment of a product-service system for renting electric-powered tools. Journal of Cleaner Production. 281, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.125245.

[20] Mert, G. and Aurich, J.C. 2015. A software demonstrator for measuring the quality of PSS. Procedia CIRP (2015), 209–214.

[21] Mert, G., Waltemode, S. and Aurich, J.C. 2014. Quality assessment of technical product-service systems in the machine tool industry. Procedia CIRP (2014), 253–258.

[22] Mo, J.P.T. 2012. Performance assessment of product service system from system architecture perspectives. Advances in Decision Sciences.

[23] Mustafa, M., Sivarajah, U., Ziaee, A. and Missi, F. 2020. Servitization implementation in the manufacturing organisations: Classification of strategies , definitions , benefits and challenges. International Journal of Information Management. 55, July (2020), 102206. DOI:https://doi.org/10.1016/j.ijinfomgt.2020.102206.

[24] Negash, Y.T., Calahorrano Sarmiento, L.S., Tseng, M.L., Jantarakolica, K. and Tan, K. 2021. Sustainable product-service system hierarchical framework under uncertainties: The pharmaceutical industry in Ecuador. Journal of Cleaner Production. 294, (2021), 126188. DOI:https://doi.org/10.1016/j.jclepro.2021.126188.

[25] Nijssen, E.J., Hillebrand, B., Vermeulen, P.A.M. and Kemp, R.G.M. 2006. Exploring product and service innovation similarities and differences. International Journal of Research in Marketing. 23, 3 (2006), 241–251. DOI:https://doi.org/10.1016/j.ijresmar.2006.02.001.

[26] Pecorari, P.M. and Lima, C.R.C. 2021. Correlation of customer experience with the acceptance of product-service systems and circular economy. Journal of Cleaner Production. 281, (Jan. 2021). DOI:https://doi.org/10.1016/j.jclepro.2020.125275.

[27] Rondi, E., de Massis, A. and Kraus, S. 2021. Servitization through open service innovation in family firms: Exploring the ability-willingness paradox. Journal of Business Research. 135, (2021), 436–444. DOI:https://doi.org/10.1016/j.jbusres.2021.06.040.

[28] Sachdev, S.B. and Verma, H.V. 2004. Relative Importance of Service Quality Dimensions: A Multisectorial Study. Journal of Services Research. 4, 1 (2004), 93–116.

[29] Sakao, T. and Neramballi, A. 2020. A product/service system design schema: Application to big data analytics. Sustainability (Switzerland). MDPI AG.

[30] Salwin, M., Kraslawski, A., Lipiak, J., Gołębiewski, D. and Andrzejewski, M. 2020. Product-Service System business model for printing houses. Journal of Cleaner Production. 274, (Nov. 2020). DOI:https://doi.org/10.1016/j.jclepro.2020.122939.

[31] Sassanelli, C., Pezzotta, G., Pirola, F., Terzi, S. and Rossi, M. 2016. Design for Product Service Supportability (DfPSS) Approach: A State of the Art to Foster Product Service System (PSS) Design. Procedia CIRP (2016), 192–197.

[32] Wang, N., Ren, S., Liu, Y., Yang, M., Wang, J. and Huisingh, D. 2020. An active preventive maintenance approach of complex equipment based on a novel product-service system operation mode. Journal of Cleaner Production. 277, (Dec. 2020). DOI:https://doi.org/10.1016/j.jclepro.2020.123365.

[33] Withers, B. and Diego, S. 2000. Does ISO 9000 Certification Affect the Dimensions of Quality Used for Competitive Advantage? European Management Journal. 18, 4 (2000), 431–443.

[34] Wu, C., Chen, T., Li, Z. and Liu, W. 2021. A function-oriented optimising approach for smart product service systems at the conceptual design stage: A perspective from the digital twin framework. Journal of Cleaner Production. 297, (May 2021). DOI:https://doi.org/10.1016/j.jclepro.2021.126597.

[35] Xin, Y., Ojanen, V. and Huiskonen, J. 2018. Knowledge Management in Product-Service Systems - A Product Lifecycle Perspective. Procedia CIRP (2018), 203–209.

[36] Yang, X., Wang, R., Tang, C., Luo, L. and Mo, X. 2021. Emotional design for smart product-service system: A case study on smart beds. Journal of Cleaner Production. 298, (May 2021). DOI:https://doi.org/10.1016/j.jclepro.2021.126823.

[37] Yin, D., Ming, X., Liu, Z. and Zhang, X. 2020. A fuzzy ANP-QFD methodology for determining stakeholders in product-service systems development from ecosystem perspective. Sustainability (Switzerland). 12, 8 (Apr. 2020). DOI:https://doi.org/10.3390/SU12083329.

[38] Yoon, B., Kim, S. and Rhee, J. 2012. An evaluation method for designing a new product-service system. Expert Systems with Applications. 39, 3 (Feb. 2012), 3100–3108. DOI:https://doi.org/10.1016/j.eswa.2011.08.173.

[39] Zhang, Z., Xu, D., Ostrosi, E. and Cheng, H. 2020. Optimization of the product-service system configuration based on a multilayer network. Sustainability (Switzerland). 12, 2 (Jan. 2020). DOI:https://doi.org/10.3390/su12020746

Striving in Banking Industry in Indonesia Through Technology Information Investment Effectiveness

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ABSTRACT

Digitalization in the banking industry has rapidly sped up, especially during this pandemic era. Customers' needs and expectations push banking companies to invest in technology even more, forcing banks to select and implement the technology prudently and effectively. This study aims to analyze the effect of information technology investment effectiveness in the banking industry in Indonesia. The data in this study was obtained from 33 banks listed on the Indonesia Stock Exchange (IDX), from 2015-2020. Data analyzed using Eviews 9. The results of this research show that there is a relationship between information technology investment on bank performance that is measured by two parameters, the first one is a financial performance using return on asset (ROA) and the second one is bank efficiency using cost efficiency (CEFF). The effectiveness of information technology investment in this study was measured by Total Investment Per Employee (TIPE), Employee Expense per total Asset (EEAR), the total number of Automatic Teller Machine (ATM), and Investment Computer Software (ICS). The results are, for TIPE and total of ATM have a positive and significant relationship on bank performance whereas the EEAR and ICS have a negative and significant relationship to bank performance. This study provides implications and unique insights about the role of management in managing the information technology investment effectiveness for bank performance.

KEYWORDS

Information Technology Investment, Bank Performance, Technology Investment Efficiency, TIPE, EEAR

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1 INTRODUCTION

In this era of digitalization in the banking industry, ignorance of prudent investment in the technology will impact greatly such as monetary loss, high-cost expenditures, increasingly large levels of competition, difficulties in supporting complex business operation processes and resource management (Roy & Thangaraj, 2020). The needs of information technology innovation must be adjusted to the needs of each business so it can maximize its impact on company performance. Previous research is divided into two opinions regarding the influence of information technology on the performance of banking companies. Some research showed that Information technology innovations in the banking industry will bring changes that can change the map of competition and prevent banking companies from bankruptcy (Gunawan & Serlyna, 2018) and will transform efficient business operations, reduce operational costs and increase ease of access from business operations (Le & Ngo, 2020), and also can reduce labor costs (Roy & Thangaraj, 2020). This research states that the effect of information technology on banking can support operational performance through the development of financial products needed by the market, can develop alternative banking channels in addition to using conservative methods through branch offices and reduce costs (Takeda, Takeda, Takemura, & Ueda, 2021). The other side of information technology investment is that it requires large costs and requires large resources in the implementation process and if not followed by a maximum application for business needs can reduce profitability, which proves the existence of a tech-pro paradox (Roy & Thangaraj, 2020). This result states that information technology has a negative influence on bank performance, known as the theory of profitability paradox or Solow paradox. Other research in Lebanese banking studied another variable of influence in information technology investment, especially in automated teller machines (ATMs), Total Point of Sales (POS), and investment in banking software on ROA (Le & Ngo, 2020). Another study by Abd. Karim, Anuar, & Mohd. Khan (2020), showed the effect of information technology investment in this study will use variables such as technology investment per employee (TIPE), employee expense per total asset (EEAR), number of ATMs, and investment in computer software (ICS). Measurement in the bank company divides into two parts; the first is the bank's financial performance which is measured through ROA and the second part using bank efficiency in the form of cost efficiency (CEFF) which will be measured using the data envelopment analysis (DEA) method.

2 LITERATURE REVIEW

2.1 Conceptual Framework

There are four independent variables in determining the information technology investment effectiveness used in this study: Technology Investment Per Employee (TIPE), Employee Expense per Total Asset (EEAR), number of automated teller machines (ATMs)

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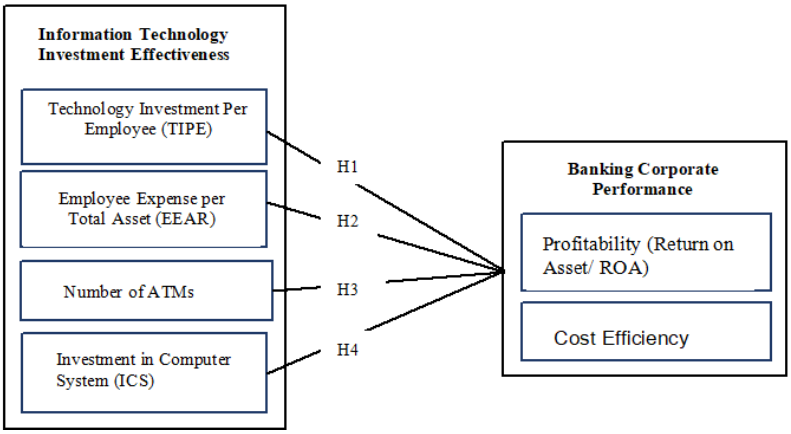

Figure 1: : Conceptual Framework

and investment in the computer system (ICS). The first variable, Technology Investment Per Employee (TIPE), study in Indian banks shows TIPE has a significant value and has a positive effect on company performance (Chhabra Roy, 2021). The second variable is Employee Expenses to Total Assets (EEAR). Based on research by Chhabra Roy (2021) for Employee Expenses to Total Assets (EEAR) has a negative effect on the performance of banking companies because the existence of technology investments is not supported by the training of its employees in their operations which can reduce the efficiency and motivation of workers to reduce profitability. The third variable is a large number of automated teller machines (ATMs) owned by banking companies, which according to previous results reports have a positive effect on the company's performance because the existence of ATMs can reduce operational costs such as maintenance costs for branches, labor costs and other related costs (Le & Ngo, 2020). The last variable is the amount of investment in computer software (ICS). The previous research had two different views, first related to the profitability paradox or Solow paradox theory that argues investment in technology, both software, hardware, and other IT services, had a negative effect on the performance of banking companies. On the other hand, research by Doluca & Doluca (2012) states that investment in computer software, especially enterprise resource planning (ERP), has a positive influence on company performance. Based on the studies above, the following is the conceptual framework of this study:

2.2 Hypothesis Development

The amount of Technology Investment Per Employee (TIPE) in banking companies has a positive influence on the company's performance and efficiency. This report is supported by research by Indian banks, where TIPE has significant value and positively affects the company's performance and efficiency because the large investment in technology per employee shows that companies are committed to utilizing their resources efficiently such as in the application of training to improve company performance and efficiency (Chhabra Roy, 2021). Meanwhile, research in Kuwait states that Al Ali (2020) total assets per total number of employees have a significant and positive influence on financial performance (ROA and ROE). Based on the above research can be formulated hypotheses as follows: Based on the discussion above, a hypothesis is formulated as follows:

H1: There is an effect between Technology Investment per Employee (TIPE) on the performance of bank companies

Based on research by Chhabra Roy (2021) Employee Expenses to Total Assets (EEAR) has a significant and negative effect on the performance and efficiency of banking companies because the investment in technology is not supported by the training of its employees in their operations which can reduce the efficiency and motivation of workers to reduce the performance and efficiency of the company. The results of this research are also supported by previous research by Roy & Thangaraj (2020) that Employee Expenses per Total Asset (EEAR) have a significant and negative effect on the company's financial performance. Based on the above research can be formulated hypotheses as follows:

H2: There is an effect between Employee Expenses per total Asset (EEAR) on the performance of the bank company

A large number of automated teller machines (ATMs) owned by banking companies has a significant and positive effect on performance and the company because the existence of ATMs can reduce operational costs such as maintenance costs for branches, labor costs, and other related costs (Le & Ngo, 2020). This result is supported by El-Chaarani & Abiad (2018) in Lebanon, that the number of ATMs has a significant and positive influence on the performance and efficiency of the company because in Lebanon ATMs are needed by consumers compared to having to go to branch offices. Contrary to the results of research from Sathye & Sathye (2017) which states that the number of ATMs has a significant and negative effect on bank efficiency and also financial performance. This can happen because the existence of ATMs cannot directly reduce the number of workers. After all, there is still a lot of work done manually so management must have a precautionary in determining their investment. Based on the above research can be formulated hypotheses as follows:

H3: There is an effect between the number of Automated Teller Machines (ATMs) on the performance of bank companies

Solow paradox theory reveals that technology investments in both software, hardware, and other IT services have a negative influence on the performance of banking companies. This statement is supported by Doluca & Doluca (2012) using data on banking companies in the United States as many as 157 banks. Solow paradox is also supported by Kabiru & Farouk (2015) through his research in Nigerian banking companies, that the cost of technology investment (software, hardware, and other services) has a significant and negative influence on financial performance that can be measured using return on equity (ROE), return on assets (ROA) and earnings per share (EPS). However, the same research by Doluca & Doluca (2012) states that investment in computer software, especially enterprise resource planning (ERP), has a significant and positive influence on the performance and efficiency of bank companies if followed by organizational restructuring to adjust the updated business operations. Based on the above research can be formulated hypotheses as follows:

H4: There is an effect between the amount of investment in computer software (ICS) on the performance of bank companies

3 RESULTS AND DISCUSSION

Hypothesis testing uses the results of the analysis of the selected model by comparing the degree of probability and the degree of significance (α =0.001, 0.05 and 0.01). Therefore, the following describes the effect of each independent variable on the dependent variable:

H1: There is a significant positive effect between Total Investment per Employee (TIPE) and the bank's company performance

The Log_TIPE variable has a coefficient value of -0.0014 for ROA and 0.0977 for CEFF, where the probability against ROA and CEFF respectively is 0.7560 and 0.0190. Based on these results, it shows that Log_TIPE or Total Investment Per Employee has a significant positive influence on CEFF or cost efficiency and is not significant on ROA. The H1 hypothesis is accepted because the Total Investment per Employee (TIPE) has a significant and positive influence on the performance of the Bank's company. Total Investment Per Employee (TIPE) has a significant positive influence on cost efficiency in Indonesian banks because management shows a willingness to process its human resources. Company management provides support in information technology investment so that the ability of employees can continue to keep up and in the end will provide opportunities for employees to work efficiently for the company. These results are in line with several previous studies by Chhabra Roy (2021) which stated that the amount of Technology Investment Per Employee (TIPE) in banking companies has a significant positive influence on company performance and efficiency.

H2: There is a significant negative effect between Employee Expenses per total Asset (EEAR) on the bank's company performance

The result for the independent variable EEAR has a coefficient to ROA and CEFF respectively is -0.8145 and 0.8675 while for the probability values it is 0.0001 and 0.6466. Based on these results EEAR has no significant influence on bank efficiency or cost efficiency (CEFF). On the other hand, EEAR has a significant negative influence on financial performance, namely ROA. In conclusion, EEAR has a significant negative influence on the performance of bank companies. The results of this study show that the value of EEAR has a significant negative influence on financial performance because it is widely found in an organization or company that is carrying out digital transformation factors that often hinder. After all, employees were previously unfamiliar with the use of technology and this is a challenge for management to implement organizational change management to maximize the technological transformation applied. The results of the study for the influence of EEAR on company performance that was significantly negative were also stated by previous research by Chhabra Roy (2021) and Roy & Thangaraj (2020) where Employee Expenses to total Assets (EEAR) has a significant negative influence on the performance and efficiency of banking companies because of the presence of technology investment but is not supported by the training of its employees in its operations which can reduce efficiency and motivation of workers thereby reducing the company's performance and efficiency.

H3: There is a significant positive effect between the number of Automated Teller Machines (ATMs) on the bank's company performance

Another variable in this study is the number of ATMs that have coefficients against ROA and CEFF respectively 0.0207 and 0.2429 and the probability value is 0.0572 against ROA and 0.0134 against CEFF. This means that the ATM variable has a significant positive influence both on financial performance (ROA) and bank efficiency (CEFF) so that the H3 hypothesis is accepted or ATMs have a significant positive influence on the Bank's performance. The number of ATMs for bank companies in Indonesia has an important role because most people need ATM machines to support banking or non-banking activities such as withdrawing cash, depositing cash, paying credit instalment bills, paying household needs bills (electricity, telephone, regional drinking water companies (PDAMs) and others). The large need of the Indonesian people for ATM machines has become a preference for the public in choosing a bank that has an ATM network that is easily accessible and will increase transactions to improve the company's financial performance. In addition, ATMs can also reduce the need for operational costs in terms of human resources, so that the bank company's human resources can be more focused on the company's start-up activities and will result in bank efficiency on the cost side. The results of this study are supported by several studies that state the same thing that the number of ATMs has a significant positive influence on bank performance. One of them is research from Le & Ngo (2020) and El-Chaarani & Abiad (2018) which resulted in the conclusion that a large number of automated teller machines (ATMs) owned by banking companies has a significant positive effect on performance and companies.

H4: There is a significant negative effect between the amount of investment in computer software (ICS) on the performance of bank companies

The results of this study for the fourth independent variable, the ICS, have coefficient values against ROA and CEFF of -0.0007 and -0.1833 respectively. Meanwhile, the probability value of ICS against ROA is 0.9255 which means it is insignificant while the probability value of ICS against CEFF is 0.0038 which means it is significant at alpha 0.01. These results show that ICS has a significant negative influence on bank efficiency (CEFF). The results of this study show the validity of the Solow paradox theory which

reveals that investment in technology, both software, hardware and other IT services, has a negative influence on the performance of banking companies. Investment in information technology on company performance does not have an instant impact because it requires changes that involve changes in the operational level that must be supported by human resources. In the second analysis, information technology investment must also be carried out with careful planning and must be made in a blueprint or road map following future business targets, so that every investment spent can have a maximum impact on the company. The results of this study are supported by Doluca & Doluca (2012) and Kabiru & Farouk (2015) which support the Solow paradox theory, that the cost of technology investment (software, hardware and other services) has a significant negative influence on financial performance.

4 CONCLUSION

The conclusions that can be drawn from the results of this study are as follows:

1. Total Technology Investment per Employee (TIPE) is not significant to financial performance, measured by Return On Assets (ROA), but TIPE has a significant positive influence on the performance of bank companies as measured by cost efficiency (CEFF).

2. Employee Expenses per Total Asset (EEAR) has a significant negative influence on the performance of bank companies as measured through variables of financial performance, return on assets (ROA), while EEAR is not significant to cost efficiency (CEFF).

3. The number of ATMs owned by banks has a significant positive influence on the performance of bank companies both measured through financial performance, ROA and also measured through bank efficiency, CEFF.

4. Investment Computer Software (ICS) which is a combination of total information technology investment is not significant to the company's financial performance, ROA, while ICS has a significant negative influence on the performance of bank companies as measured through the bank efficiency approach, namely CEFF.

5 IMPLICATIONS

5.1 For Banking Companies

The results of this study explain how the effectiveness of information technology investment had impact on company performance measured by Return on Asset (ROA) and bank efficiency as measured through cost efficiency. The management of banking companies should pay attention to the ratio of Total Information Technology Investment to the number of employees, which in this study has a significant and positive influence on the performance of bank companies. This means that the amount of information technology must be balanced with the optimal number of employees.

A large number of ATMs in Indonesia is still favoured by customers because it is proven in this study to be able to improve company performance both from ROA and CEFF performance.

As for the Total Investment in information technology itself, management must be careful in setting the budget because in this study it produces a significant negative influence on company performance where managers must also balance other strategies such as organizational restructuring.

5.2 For Investors

For investors who want to buy shares for bank companies listed on the Indonesia Stock Exchange (IDX) can study the company's annual report related to whether the company already has a budget for information technology investment and then can also see the development of information technology that has been implemented and can be utilized by consumers. Based on the results of this study, investors must carefully have several parameters to measure information technology investment carried out by bank companies such as the number of ATMs and also the total investment in information technology on the number of employees (TIPE) proven to be able to have a significant positive influence on the company's performance. On the other hand, the value of the investment in computer software and employee expenses per total asset (EEAR) has a significant negative impact on the performance of bank companies. Investors must conduct an in-depth analysis of information related to information technology investment information for bank companies that will be invested in capital.

5.3 For Regulators

In this study, regulators or the government can use it as a consideration in making and clarifying regulations for banking companies in the application of information technology. It is hoped that regulations made with strict monitoring can encourage companies to apply information technology in the banking industry to improve their company's performance. The government can also implement regulations through relevant agencies or institutions to clarify the provisions of the application of information technology, especially now that digital banks in Indonesia are very developed so that healthy and fair regulations are obtained for all parties involved.

6 LIMITATIONS AND SUGGESTIONS

Independent variables for the effectiveness of information technology investment consist of 4 variables; Total Investment Per Employee (TIPE), Employee Expenses per total asset (EEAR), number of ATMs, and Investment Computer Software (ICS). The dependent variables for bank company performance in the study are divided into; the company's financial performance as measured through return on assets (ROA) and bank efficiency as measured through cost efficiency (CEFF). Suggestion for later research in the same field is to provide company size variables (Abd. Karim et al., 2020). Another study by Gunawan & Serlyna (2018) used the dependent variable earnings per share (EPS) in looking at its effect on information technology investment and using mobile banking and internet banking to become variable parameters for information technology investment (El-Chaarani & Abiad 2018).

REFERENCES

[1] Roy, N. C., & Thangaraj, V. (2020). Investment in Technology: Does It Proliferate the Profitability and Performance of the Indian Banks? 36, 19–44. https://doi.org/10.1108/s0196-382120200000036002

[2] Gunawan, H., & Serlyna, S. (2018). Impact of Information Technology Investment To Financial Performance on Banking Sector. Journal of Applied Managerial Accounting, 2(1), 41–46. https://doi.org/10.30871/jama.v2i1.700

[3] Takeda, F., Takeda, K., Takemura, T., & Ueda, R. (2021). The impact of information technology investment announcements on the market value of the Japanese regional banks. Finance Research Letters, 41, 101811. https://doi.org/10.1016/j.frl.2020.101811

[4] Le, T. D., & Ngo, T. (2020). The determinants of bank profitability: A cross-country analysis. Central Bank Review, 20(2), 65–73. https://doi.org/10.1016/j.cbrev.2020.04.001
[5] Abd. Karim, M. Z., Anuar, A. R., & Mohd. Khan, S. J. (2020). Information Technology and Cost Efficiency in Malaysian Banking Industry. Malaysian Management Journal, (January), 46–58. https://doi.org/10.32890/mmj.7.2.2003.8612
[6] Chhabra Roy, N. (2021). Banks and their technology investment decision are aligned or not – an experience of Indian banks. Journal of Facilities Management, 19(1), 1–20. https://doi.org/10.1108/JFM-04-2020-0020
[7] Doluca, H., & Doluca, H. (2012). Bank Performance and the Solow Paradox. SSRN Electronic Journal, 23529(2), 1–45. https://doi.org/10.2139/ssrn.2334878
[8] AlAli, M. S. (2020). Staff Efficiency Effects on Financial Performance: A Case Study on Kuwaiti Banks. International Journal of Business and Applied Social Science, (August), 59–63. https://doi.org/10.33642/ijbass.v6n8p8
[9] El-Chaarani, H., & Abiad, Z. (2018). The Impact of Technological Innovation on Bank Performance. Journal of Internet Banking and Commerce, 23(3). Retrieved from https://www.icommercecentral.com/peer-reviewed/the-impact-of-technological-innovation-on-bank-performance.pdf
[10] Sathye, S., & Sathye, M. (2017). Do ATMs Increase Technical Efficiency of Banks in a Developing Country? Evidence from Indian Banks. Australian Accounting Review, 27(1), 101–111. https://doi.org/10.1111/auar.12110
[11] Kabiru, B., & Farouk, U. (2015). Impact of Investment in Information Technology on Financial Performance of Nigerian Banks: Is There a Productivity Paradox? Journal of Internet Banking and Commerce, 20(1), 1–23. Retrieved from http://www.arraydev.com/commerce/jibc/

Service Quality Improvement at International Airport In Indonesia Using Service Quality And Theory Of Inventive Problem Solving (TRIZ)

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ABSTRACT

Service quality improvement at I Gusti Ngurah Rai International Airport in Indonesia needs to be done to improve service to passengers. This is done because the I Gusti Ngurah Rai International Airport in Indonesia is an international airport with a large number of passengers compared to other international airports. So it is necessary to improve quality to maintain airport performance and increase satisfaction and loyalty to passengers to visit I Gusti Ngurah Rai International Airport. This study, to improve airport passenger services by conducting initial analysis, namely determining the attributes of the airport passenger service level that need to be improved. The method used in this study uses the Servqual method and the Theory of Inventive Problem Solving (TRIZ) method. In this study, there are 28 service quality attributes based on 5 dimensions of service quality. Based on the service quality calculation, there are 7 positive gap attributes, 4 zero gap attributes, and 17 negative gap attributes. So, 17 service quality attributes indicate passengers are not satisfied with the services provided on these attributes. Based on the results of the method, the initial stage is an analysis using a cause-effect diagram to see the potential contradictions and causes of problems by the 17 attributes. So that 12 attributes cause contradictions in solving problems and 5 attributes that do not cause contradictions in solving problems. Attributes that cause contradictions are then analyzed using the TRIZ method using 39 engineering parameters, a contradiction matrix, and 40 inventive principles. Meanwhile, attributes that do not cause contradictions will be analyzed and solutions will be provided based on 40 inventive principles. Based on the results of the analysis carried out using TRIZ, it was found that the proposed improvements for each attribute were adjusted based on the principles of universality, segmentation, change parameters), taking out, mechanical vibration, preliminary action, and mechanics substitution.

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CCS CONCEPTS

• **Service System Engineering**; • **Quality Improvement**; • **Service Industry**;

KEYWORDS

Service Quality Improvement, International Airport, Service quality, TRIZ

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1 INTRODUCTION

Airport according to the Ministry of Transportation of the Republic of Indonesia [2] is an area on land and or waters with certain boundaries that are used as a place for aircraft to land or take off, board or unload passengers, loading and unload goods and places for intra and inter-agency transfers. a mode of transportation equipped with security and safety facilities for flights as well as basic facilities and other supporting facilities [1]. Indonesia has 351 airports of which more than 200 airports are managed by the Technical Implementation Unit of the Directorate General of Civil Aviation and 77 airports are managed by Regional Governments. There are also 28 airports managed by State-Owned Enterprises (BUMN), namely PT Angkasa Pura I and PT Angkasa Pura II where PT Angkasa Pura I has 13 airports and PT Angkasa Pura II has 15 airports [1]. According to research conducted [17], airports face challenges in serving passengers such as congestion in the terminal area, uneven demand, disturbances that occur in the terminal area, to external events that cannot be controlled. At I Gusti Ngurah Rai International Airport there is an increase in the number of passengers, an increase in March 2022 was recorded by 56% [17] at the departure terminal. The increase in the number of passengers requires managers to continue to improve and improve the quality of their services by taking into account the needs and expectations of service users. The services provided by the manager must be under the expectations of service users at the airport because the

manager is not only required to provide facilities but to improve and pay attention to the needs of the passengers.

The quality improvement carried out by the manager must be under the expectations of passengers so that the level of passenger satisfaction is in line with the increasing quality of services provided by I Gusti Ngurah Rai Airport. According to [22] several gaps have the potential to become obstacles in providing services to customers. One of these gaps is the gap between the manager's perception and customer expectations. Therefore, managers must know customer satisfaction and observe service quality from the consumer's point of view. Research [22] states that there are 5 dimensions of service quality, namely tangible, reliability, responsiveness, assurance, and empathy. These quality dimensions can be used to measure the quality of services provided by I Gusti Ngurah Rai Airport and passenger expectations regarding the quality of services provided. A study conducted [17] used the service quality method with 5 dimensions of service quality which resulted in a negative gap in some of the service quality attributes studied. The negative gap indicates that there is a significant difference between the manager's perspective and the passenger's expectations so this attribute must be improved by the Soekarno-Hatta Airport manager to improve the quality of its services. In addition, the research combines two methods, namely the service quality method and the Theory of Inventive Problem Solving (TRIZ) method to improve the quality of service on airlines. The study [21] identified problems that occur in Airways using the service quality method in the form of flight delays due to bad weather, disturbances in air traffic, and problematic facilities resulting in delays in departure due to the accumulation of passengers. can be solved using the TRIZ method. The solutions given to these problems are in the form of additional services for passengers when delaying departures, increasing air traffic volume capacity, as well as periodic maintenance of the facilities at the airport.

Therefore, I Gusti Ngurah Rai International Airport needs to know the level of quality of services provided and customer perceptions of the quality of services provided. The service quality method is one tool that can be used to determine the quality gap in service at I Gusti Ngurah Rai International Airport. Service quality is measured based on 5 dimensions of service quality by including several attributes in each measured quality dimension. After knowing the attributes that need to be improved to improve the quality of service, it is necessary to solve problems on these attributes

2 LITERATURE REVIEW.

2.1 Service

Service is any action or performance offered by one party to another, which is essentially intangible and does not cause any transfer of ownership [19]. Service is any action or performance offered by one party to another that is eaten and made at the same time and provides added value and is essentially intangible and does not result in a transfer of ownership [20]. In addition, a service is an economic activity that is offered by one party to another such as employing time-based performance to bring the desired results to the recipient for which the buyer is responsible and the service customer expects to get value from access to goods, labor, professional skills. , facilities, networks, and systems in exchange for time, money, and effort [20].

2.2 Service Quality

Quality according to the American Society for Quality quoted quoting the overall quality of the identity and character of a product or service in terms of its ability to meet predetermined desires in other words the quality of a product or service is the extent to which a product or service can meet its specifications. [17]. However, [6] describes quality as something that is different for different people in terms of duration and fit, or is said to be fit for purpose. Quality also describes quality as a dimension to take into account that an object or service already has a value for what is desired in other words an object or service is considered to have quality if it plays a role or has value for what is desired [7].

2.3 Service Quality Method

The service quality method is a method of an instrument to measure service quality in their research in the service sector. The measurement of service quality in this service quality model is based on a multi-item ratio designed to measure the quality of customer desires and perceptions and the gap between the two on 5 dimensions of service quality, namely tangible, reliability, responsiveness, assurance, and empathy. In the service quality model, there are 5 types of quality gaps that have the potential to become obstacles in providing services to customers [22].

2.4 Validity and Reliability Test

A validity test is testing the level of ability of a research instrument to see whether the information is under the problems studied [13]. A validity test is also referred to as a dimension that proves the validity and validity. The method of validity of an instrument is said to be valid if it can measure something it wants and can convey information from the variables studied appropriately [13]. The level of instrument validity proves the extent to which information is collected from a reflection of the variables studied. A reliability test is a test carried out to identify whether the measurement results remain unchanged even though it is carried out by measuring 2 or more times on similar symptoms with similar measuring instruments [13].

2.5 Theory of Problem Solving

TRIZ or Theory of Inventive Problem Solving comes from the Russian language, namely "Theoriya Resheniya Izobreatatelskihh Zadach" developed by Genrich Altshuller [15]. TRIZ has stages that are used to solve problems by starting with specific problems and identifying contradictions that exist in that problem. [16]. The TRIZ method supports creativity and innovation in the manufacturing industry so that the capabilities of the TRIZ method can be applied to non-technical problems. One example of a non-technical area is the development of service quality and combined with TRIZ

3 METHODOLOGY

The steps of the research methodology carried out in this study began with determining the servqual attribute.

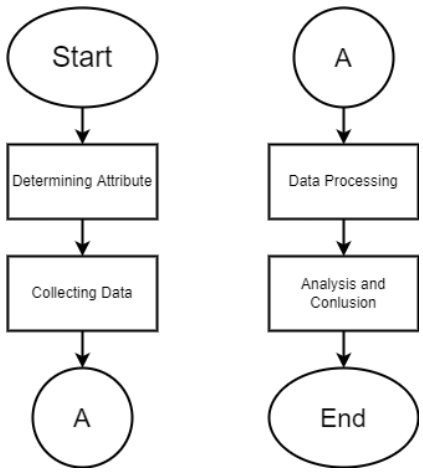

Figure 1: Research Methodology

- Determining the servqual attribute based on 5 dimensions of service quality namely tangible, reliability, responsiveness, assurance, and emphaty
- Then determining the number of samples, preparing questionnaires and distributing and collecting questionnaires at the I Gusti Ngurah Rai Airport terminal.
- Then the results of the questionnaire were tested for validity and reliability to find out whether the data obtained were reliable and used as a measuring tool to obtain information in this study. Then do the calculation of the gap servqual type 5 were based on these calculations obtained attributes with a positive gap, zero gap, and negative gap. Servqual gap calculation type 5 is carried out at the item-by-item level where each attribute is calculated based on the servqual calculation
- The results of the negative gap will then be analyzed solved using 40 principles of the TRIZ Method.

4 RESULT AND DISCUSSION

4.1 Deterimination of Servqual Attributes

At the stage of determining the servqual attribute, it is determined based on 5 dimensions of service quality, namely physical evidence (tangible, reliability, responsiveness, assurance), and empathy. The servqual attribute is obtained based on the elaboration of various sources such as Skytrax surveys, Airport service quality, and several other references. Servqual attributes in research based on 5 dimensions of service quality can be seen in Table 1.

4.2 Deterimination of Number Samples

Determination of the number of samples is done by using the Bernoulli formula approach. The following is the Bernoulli formula that will be used to determine the number of samples in this study.

$$N \geq \frac{\left(Z_{\frac{\alpha}{2}}\right)^2 pq}{e^2} \tag{1}$$

In this study, the level of confidence or used is 95% so that the proportion of the number of questionnaires that are considered correct is 0.95 and the proportion of the number of questionnaires that are considered incorrect is 0.05. As for the error tolerance used is 5% where the error that may occur is 5%. So, the calculation of the number of samples as follows:

$$N \geq \frac{(1.96)^2 x\ 0.95x0.95}{0.05^2}$$
$$N \geq 72.99$$

So based on the calculation of the minimum number of samples needed in this research is 73 respondents.

4.3 Validity and Reliability Testing

After the questionnaires were distributed and collected, then the validity and reliability of the data were tested. The test is carried out by correlating the statement items with a total value of 77 respondents. The stages in the validity test are as follows:

1. Determining Determine hypothesis on validity testing

H0 : questionnaire is valid

H1 : questionnaire is invalid

- Determine R Table

Determine R Table uses alpha (α) is 0.05 and the number of samples is 77 respondents with degrees of freedom in the validity test of 75. So that the r table is 0.227.

- Determine r Count

Determination of the calculated r using the equation described in the previous section.

- Determine Decision Base on r Count

The respondent's answer is said to be valid if r arithmetic is greater than r table and if r arithmetic is not greater than r arithmetic then the respondent's answer is invalid.

- Decision

The final result can be concluded that H0, so that there is a correlation between each statement item with the total assessment value and the questionnaire can be said to be valid

The reliability test was carried out using the reliability test on the SPSS software. The data is said to be reliable if the Cronbach's alpha value is greater than 0.6. From these results obtained alpha values as follows:

- D Alpha Value Passenger Expectations = 0.963
- Alpha Value Passenger Satisfaction = 0.972

From these two values, it is known that the expression of expectations and passenger satisfaction has a value of more than 0.6 and it can be concluded that the questionnaire is reliable.

4.4 Servqual Counting

After knowing the average passenger expectation score and the average passenger satisfaction, the next step is to calculate the gap servqual type 5 by reducing the average passenger expectation score with the average passenger satisfaction score. The results of the calculation of the type 5 servqual gap can be seen in Figure 6. In Figure 6 it can be seen that the type 5 servqual gap calculation produces 7 positive gaps, 4 zero gaps, and 17 negative gaps. So that there are 7 attributes that indicate passengers are very satisfied

Table 1: Servqual Attributes

Attri	Description	Attri	Description
T1	Coolness and comfort at the terminal	RS1	Security guards respond quickly to requests for help
T2	Cleanliness at the terminal such as waiting rooms, check-in areas, and others.	RS2	Goods inspection time (x-ray) when served is fast (less than 3 minutes)
T3	The capacity at the terminal is sufficient to accommodate passengers	RS3	Check-in process time when served is fast (less than 3 minutes)
T4	There are directions that make it easy to find the needed places such as bathrooms, information rooms, gates, and others.	RS4	Queuing time at check in is fast (Less than 15 minutes)
T5	The physical appearance of the terminal is attractive (such as murals, carvings, etc.).	RS5	Fast baggage reception waiting time (Less than 15 minutes)
T6	The number of trolleys at the terminal is very sufficient	A1	Level of courtesy and friendliness of airport staff
T7	The airport provides comfortable seating	A2	The quality of information provided to passengers at the terminal is adequate
T8	The number of seats in the terminal is sufficient	A3	The officer's fair attitude to every passenger
T9	The number of trash bins at the terminal is sufficient	A4	Skills and knowledge of officers in serving passengers at the terminal
T10	The number of ATMs in the terminal is sufficient	A5	Items in the trunk are not damaged and safe
T11	Cleanliness in the bathroom	E1	Terminal staff give more personal attention to passengers
T12	There is adequate Wifi in the terminal area	E2	Officers at the terminal who are capable and responsive in serving passengers
T13	The number of charging points at the terminal is sufficient	E3	Availability of facilities in providing advice and criticism to airport managers
T14	Crowded changing rooms for babies and breastfeeding in adequate terminals		

with the services provided, 4 attributes that indicate passengers are satisfied with the services provided, and 17 attributes that indicate passengers are not satisfied with the services provided. The 17 attributes that produce the negative gap are then solved using the TRIZ method.

The servqual calculation produces 3 gaps, namely a positive gap, a zero gap, and a negative gap. The gap is obtained from the calculation of the average value of passenger expectations minus the average value of passenger satisfaction on each attribute. The results of the calculation of the average value of passenger expectations can be seen in Figure 4. And the results of the calculation of the average passenger satisfaction can be seen in Figure 2.

4.5 Improvement with TRIZ Attributes

There are 17 attributes that produce negative gaps, namely the attributes T2, T6, T7, T9, T10, T11, T14, RL1, RL2, RS1, RS3, A1, A2, A3, A4, A5, and E2. The following is a proposed improvement on the attributes that result in a negative servqual gap using the TRIZ method.

1. On the attributes of cleanliness in terminals such as waiting rooms, check-in areas, etc. (T2), proposed improvements in the form of implementing standard operating procedures for terminal cleanliness which require cleaning staff to be a reminder to passengers and act quickly on the cleanliness of the terminal and the information board that is available

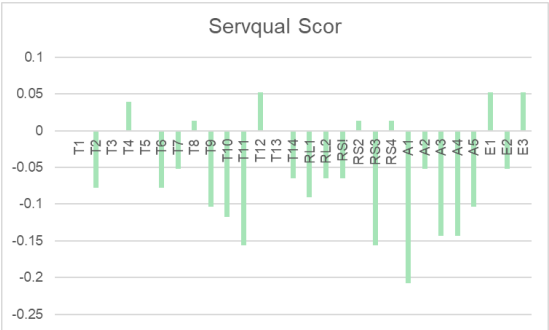

Figure 2: Servqual Scor

at the terminal can be used as a means of information related to passenger sensitivity to cleanliness at the airport in accordance with the principle of universality (6).

2. On the attribute the number of trolleys at the terminal is very sufficient (T6), the proposed improvement is in the form of the airport manager I Gusti Ngurah Rai making separate collection and collection points for trolleys and spread across the terminal area to the parking area at the airport in accordance with the segmentation principle (1).
3. At the airport attribute provides a comfortable seat (T7) the proposed improvement is in the form of changing the seat to be more ergonomic for passengers so that passengers can comfortably use the seat and the material used in the seat is easy to clean and not easy to get dirty so that the cleanliness of the seat is easy to clean. seats will be maintained according to the principle of change parameters (35).
4. On the attribute that the number of trash bins at the terminal is sufficient (T9), the proposed improvement is in the form of adding an information board or a hygiene reminder with the available trash cans so that passengers can easily find trash bins in the terminal area in accordance with the composite material principle (40).
5. On the attribute that the number of ATMs in the terminal is sufficient (T10), the proposed improvement is in the form of adding an ATM machine with an ATM link system where the ATM machine with this system allows passengers to access ATMs with various types of banks owned by each passenger and maximize the available ATM machines in accordance with the principle of Taking out (2).
6. The cleanliness attribute of the airport toilet (T11), the proposed improvement is in the form of using toilet material equipped with sensors that can clean the toilet by itself so as to ensure cleanliness of the toilet at the airport in accordance with the principle of universality (6).
7. The attribute there is a baby and breastfeeding changing room in an adequate terminal (T14) proposed improvements in the form of increasing the frequency of checking in the baby changing room and breastfeeding by officers regarding the completeness and cleanliness of the room so that the atmosphere of the room becomes more comfortable for mothers and children when they are in the room. in the room and add information about the changing room for babies and breastfeeding in the terminal by adding a logo or information on the direction board in the terminal in accordance with the principle of Mechanical vibration (18).
8. On the attributes of the reliability of facilities and equipment at the terminal (RL1), the proposed improvement is in the form of implementing preventive maintenance on facilities and equipment at the terminal by scheduling regular facility inspections before and after airport operational time in accordance with the principle of mechanical substitution (28).
9. In the attribute of goods inspection time (x-ray) at the time of fast service (RS1), the proposed improvement is in the form of adding a location for passengers to put passenger goods such as bags and suitcases carried by passengers. In addition, adding information boards regarding what items should not be carried when passing through the x-ray machine area such as belts, removing jackets, watches, and others according to the principle of segmentation (1)
10. On the attribute of queuing time during quick check-in (RS3), the proposed improvement is in the form of adding an information board related to file requirements at check-in such as identity cards, boarding passes, etc. as well as adjusting the number of passengers with the number of officers and check-in machines at the airport. terminal and implement a self- check-in system to anticipate long queues in accordance with the preliminary action principle (10).
11. The quality attribute of the information provided to passengers at the terminal is adequate (A2) proposed improvements in the form of adding an information board and equipped with notifications in the form of voice announcements by officers related to flight status, schedule changes, and changes to aircraft gates so that passengers can easily get information regarding flight according to the principle of segmentation (1).
12. On the attributes of the goods in the undamaged and safe baggage (A5), the proposed improvement is in the form of applying an automation-based machine in the transfer of goods to the aircraft baggage in order to reduce the shock of the goods when the process of moving the goods is in accordance with the principle of mechanical substitution (28).
13. At the attributes of the officers at the airport who provide services in accordance with the procedures applied (RL2), the level of politeness and friendliness of the officers at the airport (A1), the fair attitude of the officers to each passenger (A3), the skills and knowledge of the officers in serving passengers at the terminal (A4), and officers who are capable and responsive in serving passengers (E2) proposed improvements in the form of applying standard operating procedures to each officer as well as periodic assessments of officers at the airport in the attitude of officers through feedback given by passengers at the airport and training for officers on a regular basis. periodically so that officers can improve the services provided to passengers in accordance with the principle of preliminary action (10).

5 CONCLUSION AND RECOMMENDATIONS

Based on the results of the study, there were 7 attributes that obtained a positive gap, including T4, T8, T12, RS2, RS4, E1, and E3. So it can be said that passengers are very satisfied with the service on these 7 attributes. In addition, there are 4 attributes that produce a zero gap where the attributes are T1, T3, T5, and T13. And then, it can be said that passengers are satisfied with these 4 attributes. In addition, there are 17 attributes that produce negative gaps, including T2, T6, T7, T9, T10, T11, T14, RL1, RL2, RS1, RS3, A1, A2, A3, A4, A5, and E2. These attributes indicate that passengers are not satisfied with the service on these attributes and it is necessary to make improvements to the attributes that produce the negative gap. Therefore, improvements to these attributes using Theory of Inventive Problem Solving (TRIZ) obtained suggestions for improvements to each attribute are adjusted based on Inventive principles, including universality (6), segmentation (1), change parameters (35), taking out (2) , mechanical vibration (18), preliminary action (10), and mechanical substitution (28).

Limitation for this research can be in the next research by making a strategy to improve service at the airport by conducting FGD to a panel of experts and using quantitative methods to get valid results and can be used for industries that have activities in other service sectors to improve service to consumers. Beside that can added respondent to get valid research results by representing the number of airport visitors as research objects..

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REFERENCES

[1] Ap1.co.id. (2020) PT Angkasa Pura I (Persero). [online] [Accessed 28 April 2022].
[2] Ap1.co.id. (2022). PT Angkasa Pura I (Persero). [online] Available at: <https://ap1.co.id/id/information/news/detail/bandara-i-gusti-ngurah-rai-bali-raih-the-3rd-world-best-airport-2016-bandara-sultan-hasanuddin-makassar-rebut-the-most-improved-airport-in-asia-pacific-2016>[Accessed 28 March 2022].
[3] A. Zeithaml, V. Parasuraman, A. and L. Berry L. (1985). "Problems and Strategies in Services Marketing". Jurnal of Marketing Vol. 49.
[4] Barry *et al.*, (2006). TRIZ-what is TRIZ Journal: https://triz-journal.com/what-is-tri.
[5] Buol, R., (2021). Ada berapa banyak bandara di Indonesia? ini daftarnya. [online] Zonautara.
[6] Elliot. (1993). "Management of Quality in Computing Systems Education: ISO 9000 series Quality Standards Applied". Journal of System Management.
[7] Navas G., (2014). TRIZ: Design Problem Solving with Systematic Innovation.
[8] Gaspers, V. and Fontana, A., (2011). Lean Six Sima for Manufacturing and Service Industries. Vinchiristo Publication.
[9] Goetsch, D.L., & Davis, S, (1995). Introduction to Total Quality, Quality, Productivity, Competitiveness. Englewood Cliffs, NJ, Prentice Hall International Inc.
[10] Griffin, J. and Herres, R., (2002). Customer loyalty. San Francisco: Jossey-Bass.
[11] Groňroos, C., (1990). Service management and marketing. Lexington, Mass.: Lexington Books.
[12] Hubud.dephub.go.id. (2009). Direktorat Jenderal Perhubungan Udara | Data Bandara. [online] Available at: <http://hubud.dephub.go.id/hubud/website/BandaraDetail.php?id=11>[Accessed 28 March 2022].
[13] Heizer, J. dan Render, B. (2006). Manajemen Operasi, Edisi 7. Jakarta: Salemba Empat.
[14] Hestianto, N., 2011. Pengurangan Losses Material Pada Proses Pembuatan Open Can Top (OTC) Dengan Metode Six Sigma. Fakultas Teknik Universitas Indonesia,
[15] Jeeradist, T. and Sangkaew, P., (2018). TRIZ approach to innovate the collaborative decision making in aviation industry management. Social Science, pp.211 - 221.
[16] Jeeradist, T., Thawesaengskulthai, N. and Sangsuwan, T., (2022). Using TRIZ to enhance passengers' perceptions of an airline's image through service quality and safety.
[17] Kurniawan, R., Sebhatu, S. and Davoudi, S., (2017). Passanger's Perspective toward Airport Service Quality (ASQ) (Case study at Soekarno-Hatta International Airport). Journal of Civil Engineering Forum, 3(1).
[18] Lee, C., Zhao, X. and Lee, Y., (2019). Service quality driven approach for innovative retail service system design and evaluation: A case study. Computers & Industrial Engineering, 135, pp.275-285.
[19] Lovelock, C. and Gummesson, E., (2004). Whither Services Marketing?. New Jersey: Prentice Hall
[20] Lovelock, C., (2008). Service Marketing and Management. New Jersey: Prentice Hall,
[21] Pabedinskaitė, A. and Akstinaitė, V., (2014). Evaluation of the Airport Service Quality. Procedia - Social and Behavioral Sciences, 110, pp.398-409.
[22] Parasuraman, Valarie A. Zeithaml, and Leonard L. Berry. (1988). "SERVQUAL: A Multiple-Item Scale for Measuring Consumer Perceptions of Service Quality". Journal of Retailing. Vol 64 (1).
[23] Zhang, Wang, M., D. and Zhang, L., (2015). Introduction of TRIZ Theory for the Conflict-solving in the Building Energy and Environment Management System Innovation. Procedia Engineering, 121, pp.2232-2239.

Prediction of Sulfur Content in Electric Furnace Matte Using Machine Learning

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ABSTRACT

Sulfur content in Electric Furnace Matte is one of the key parameters in nickel matte process control at PT Vale Indonesia Tbk. (PTVI), a nickel matte smelter in Indonesia. Currently the compliance to standard specification is relatively low due to process variability and control limitation. The sulfur content in Electric Furnace Matte depend on sulfur addition and other operating conditions. In this research, a machine learning approach is used to predict sulfur content in Electric Furnace Matte based on selected predictors. Linear and support vector regression models were built on the training data and used to predict sulfur content on testing data. The performance of each models were evaluated and compared. The linear model shows a 0.5843 coefficient correlation between test data and prediction, with a mean square error (MSE) 0.4207. The support vector regression (SVR), a non-linear model, is built with the same predictors. SVR model improve the correlation to 0.9408 and reduce the MSE to 0.0762. The research has shown the practicality of applying machine learning in nickel matte processing and open opportunity for further research.

CCS CONCEPTS

• **Computing methodologies** → Machine learning; Learning paradigms; Supervised learning; Supervised learning by regression.

KEYWORDS

machine learning, nickel matte, linear regression multi variable, support vector regression, mineral processing

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1 INTRODUCTION

Nickel is one of the economically and strategically important metal in modern society, with major application in stainless steel, alloys, electroplating and batteries. Economic nickel resources are found in either sulfide or laterite-type ores [1]. Nickel plays crucial role in lithium-ion batteries (LIBs) production to power electric vehicle. It is used as the cathode together with cobalt, manganese, cadmium and other cathode materials. For automotive LIBs, two cathode chemistries currently dominate: lithium nickel manganese cobalt oxide (NMC) and lithium nickel cobalt aluminum oxide (NCA) [2].

The development of nickel-rich and cobalt-free cathode materials is very important for lithium battery production. It has dual competitive advantages in reducing cathode costs and increasing energy density, thereby opening a new patch for the sustainable development of electric vehicle (EV) batteries [3]. Nickel-containing cathodes make batteries lighter, smaller and provide higher energy density, resulting in a more efficient EV . It's clear that future EV batteries will employ more nickel [4].

PTVI produces nickel as nickel matte, an intermediate product, at its integrated mining and processing facility near Sorowako on the island of Sulawesi Indonesia. The nickel matte is further processed at clients offshore refinery [5]. Based on product specification at PTVI, the nickel matte contains 75-78% nickel, 18-21% sulfur, 1.5% cobalt and 0.74% iron.

Nickel matte processing at PTVI consist of five main steps from drying laterite ore, reduction of the ore, smelting the calcine, Electric Furnace Matte converting and granulation process [6]. It starts with wet ore dewatering, follow by dry ore calcination, reduction and sulfidation. It continues with calcine smelting in the electric furnace to produce Electric Furnace Matte. The final step is Electric Furnace Matte purification in the converter follow by granulation to produce nickel matte granule as the specification.

One important process in nickel matte production process is the sulfidation in reduction kiln. This process will determine sulfur content in the Electric Furnace Matte. Sulfur addition are controlled using a cascade control system based on the amount of feed and targeted sulfur consumption per ton calcine produced out of the kiln. Sulfur is added and controlled in the reduction kiln to get sulfur content in Electric Furnace Matte as the specification in 8-10% range. Figure 1 Schematic diagram kiln-furnace in nickle matte industry shows the schematic diagram of sulfur addition and its control.

The addition of the sulfur results in the sulfidation of metallic nickel and iron in the calcine. The sulfur vaporizes in the kiln

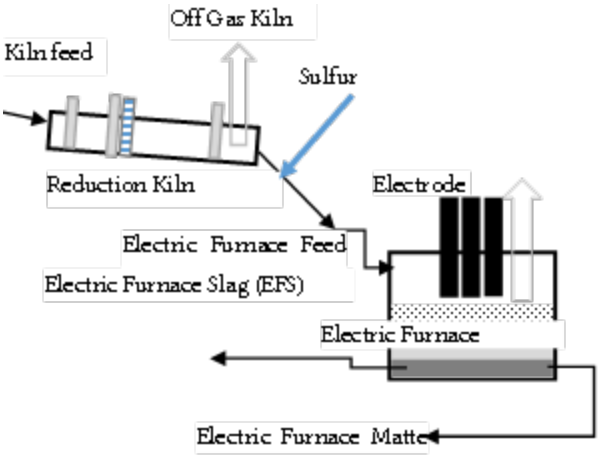

Figure 1: Schematic diagram kiln-furnace in nickel matte industry

$$3Ni_{(s)} + 2S_{(g)} \rightarrow Ni_3S_{2\,(s)}$$
$$3Ni_{(s)} + 2S_{(g)} \rightarrow Ni_3S_{2\,(s)}$$

Figure 2: Chemical reaction of sulfidation nickel and iron

discharge and reacts with nickel and iron. The reaction can be seen in the Figure 2.

At current condition, the compliance of sulfur content in Electric Furnace Matte to specification 8-10% are relatively low. Based on 2012-2021 data in PTVI, the compliance is only 55% in average. The sulfur content in Electric Furnace Matte will influence furnace and converter operation temperature. It will also impact the sulfur dioxide (SO2) emission in the operation. Too low sulfur will interrupt operation, creating delays and endanger refractory integrity both in the furnace and converter. Based on the record in equipment delay system, the low sulfur condition has caused delay in furnace operation that has impact to nickel matte production loss in average 100 t Ni per year. Meanwhile high sulfur condition will have consequence on the higher SO2 emission in the process. Both these two condition will increase probability of getting out-spec sulfur in final product nickel matte.

Many effort has been conducted in PTVI to improve effectiveness of sulfur addition in the kiln for example variation of sulfur lance injection position, trial solid sulfur addition, trial pyrite mineral addition, design of experiment to find optimum operating condition and other intensive study. Despite of the tremendous works has been done the last 10 years in the company, none of the works involve machine learning or big data analytics to take the benefit of large operating data in kiln and furnace including the stream chemistry composition.

This present works illustrated the application of machine learning for prediction of sulfur content in Electric Furnace Matte based on variable input operating conditions and also feed chemistry composition. The prediction will provide more understanding in controlling sulfur content in Electric Furnace Matte. The method used in this paper can be replicated to solve another process control issues in the nickel matte industry and in mineral processing in general.

2 LITERATURE REVIEW

Machine learning is set of methods that can automatically detect pattern in data, and then use the uncovered patterns to predict future data or to perform other kind of decision making under uncertainty [7]. The research trend on the application of machine learning in industry are still increasing. The application domain cover maintenance management, quality management, production planning and supply chain management [8]. In mineral processing, the application of machine learning trend is also increasing. It covers data-based modelling, fault detection and machine vision. The application is almost similar with the application in the industry as general [9].

Machine learning has been used to predict sintering machine productivity in steel plant. It use linear regression and artificial neural networks (ANN) models in the iron ore sintering process [10]. The input of the model are the composition of constituent material of the agglomerate and does not consider operating condition of the sintering machine. The composition of material commonly taken from sampling in certain time interval (not-continuous), while the operating condition data normally taken from online sensor and the data is available in continuous manner.

The input data that involve multi-scale time interval parameter is still rarely observed in the research of application machine learning in mineral processing. In this research an approach to utilize data with different time scale were conducted. Chemistry composition and operating condition data were integrated to build predictive model using two different algorithm: linier regression multi variable and support vector regression.

Support vector machine (SVM) is a supervised machine learning method, which was originally developed by Vapnik in 1995, with associated learning algorithm that analyze data and recognized patterns, conventionally used for classification and regression analysis. The main idea of SVM is to construct a hyperplane in a high or infinite-dimensional space based on which different types of data samples can be well separated. When the target data is continues, support vector regression (SVR) model can be developed for regression analysis. SVM can perform a non-linear classification/regression using what is called the kernel trick [11].

3 RESEARCH METHODOLOGY

This research were conducted at PTVI nickel matte processing plant in Indonesia. The observation were limited into one electric furnace and one kiln reduction, which are Reduction Kiln 5 and Electric Furnace 4. The methodology consits of data collection, data preparation, modelling and evaluation. The summary of the research methodology can be seen in Figure 3

The data are collected from September until December 2021. The four months period are selected to get adequate data and to ensure the data is relevant with recent situation. Pre-processing of data are conducted to filter the data, clean up the data, check the outlier, and make decision whether the variable has good quality data or not. The dataset when the unit operation was off for maintenance both

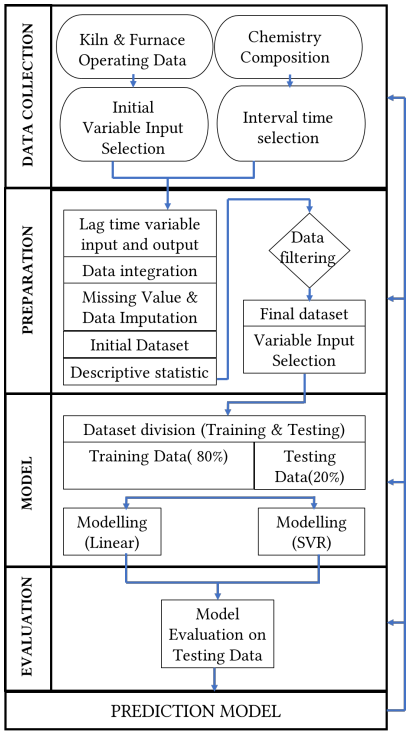

Figure 3: Research Methodology

plan/unplanned are filtered out. The data are evaluated in trend time series, histogram, correlation plot and also summaries of the descriptive statistic of the data.

Data integration are needed to combine the chemistry composition data and operating condition data. The hourly data are chosen as the interval of data observation to utilize large amount of operating data from the PIMS.

The chemistry composition data is not available in hourly basis. Different stream has different sample interval time. This cause missing data in the dataset that will be used for modelling. This missing data mechanism can be considered as Missing Completely At Random (MCAR). It means the missingness does not depend on any part of the data, either missing or observed [12]. It is appropriate to ignore the process that causes missing data if the missing data are "missing at random" [13]. To fulfil empty data in chemistry composition, the interpolation between sample are chosen. It is assumed that the feed composition in between sample interval will fall in between the current sample and next sample.

To reflect the residence time material inside furnace, 8 hours delayed time are applied for the target variable. It is assumed that the operating condition and feed composition at current time will have impact on the Electric Furnace Matte 8 hours later.

The selection of the predictors for linear model are made based on the correlation coefficient (R). Predictor that has stronger correlation coefficients will be selected. There are 68 variables involved in the data preparation. The variables that has low correlation are eliminated from the predictor. The input variables that has coefficient higher than 0.2 are considered as the predictors in the linear model development. There are total 13 variables as described in Table 1 Coefficient correlation of input variables and output variables.

Linear regression multi variable model is developed based on the selected predictors. The p-value of each coefficient are evaluated. The linear regression model is given by the following equation:

$$h_\theta = \sum_{i=0}^{n} \theta_i x_i \ (with\ x_0 = 1) \tag{1}$$

where, xi is the value of the ith input variables or predictors and the θi is the ith regression coefficient, n being the number of input variables. The cost function for the linear regression model can be calculated as sum square error of the actual data and prediction, is given by the following equation:

$$J(\theta) = \sum_{j=1}^{m} \left(h_\theta \left(x^{(j)} \right) - y^{(j)} \right)^2 \tag{2}$$

Where, $h_\theta(x^{(j)})$ represents the value of the predicted value of j-th dataset and $y^{(j)}$ represents the output value of j-th dataset, m is the total number of dataset. Analytical method was used in this work to minimize the cost function (J) to find out the regression coefficient. The p-value of each term was also calculated.

The predictor that has p-value higher than 0.05 indicate the null hypothesis of the coefficient to be 0 cannot be rejected so the predictor is removed from the model. Using the R-Studio, the model is built on the training data set that randomly picked from 80% of dataset. The rest 20% of the dataset will be used as testing data to evaluate the model. The model are evaluated for its correlation coefficient (R), mean absolute error (MAE), mean squared error (MSE) and root mean squared error (RMSE).

The model regression based on support vector machine principle for classification was used to improve the prediction. Based on the selected predictor used in linear model and cross validation of other variable that might improve the model performance, support vector regression (SVR) model is built.

4 RESULT

The performance of linear regression model was evaluated on the training dataset. The predictors were selected based on the value of correlation coefficient. Only predictors with correlation coefficient above 0.20 were selected. There are 13 input variables selected. Furthermore, the model was evaluated using unknowns which is testing dataset. Performances of the model on the testing dataset were evaluated.

For the linear model, the regression coefficient of predictors are found with minimizing cost function in the training dataset. There are two predictors that failed to reject null hypothesis that the coefficient is equal to 0; the p-value were higher than 0.05. Those variables are the temperature of Thermocouple 8 in kiln and stack temperature in. Therefore another linear model is developed with 11 predictors (excluding temperature Thermocouple 8 and stack temperature) with the same approach.

Further evaluation showed that the adjusted R-squared for the model is 0.3054, F-statistic 76.96 and p-value <2.2e-16. It is indicating that the regression model with multi variable input are statistically significant.

The model also showed that the cascade sulfur, temperature roof in feed bin 7 chute B and the ore feed rate has negative coefficient

Table 1: Coefficient correlation of input variables and output variables

No	Input Variables (x)	Output Variable (y)	Coefficient Correlations x and y
1	x45_k5_temp_exit	Y02_EFM_S	0.32
2	x34_f4_temp_roof_c6b	Y02_EFM_S	0.28
3	x41_k5_rate_coal	Y02_EFM_S	0.28
4	X03_EFS_Co	Y02_EFM_S	0.26
5	x32_f4_temp_roof_c2b	Y02_EFM_S	0.25
6	x37_f4_temp_roof_c5b	Y02_EFM_S	0.24
7	x29_f4_temp_stack	Y02_EFM_S	0.23
8	x49_k5_temp_tc8	Y02_EFM_S	0.21
9	x50_k5_temp_tc10	Y02_EFM_S	0.21
10	x48_k5_temp_tc6	Y02_EFM_S	0.2
11	x38_k5_ore	Y02_EFM_S	-0.32
12	x33_f4_temp_roof_c7b	Y02_EFM_S	-0.33
13	x61_k5_cascade_sulphur	Y02_EFM_S	-0.4

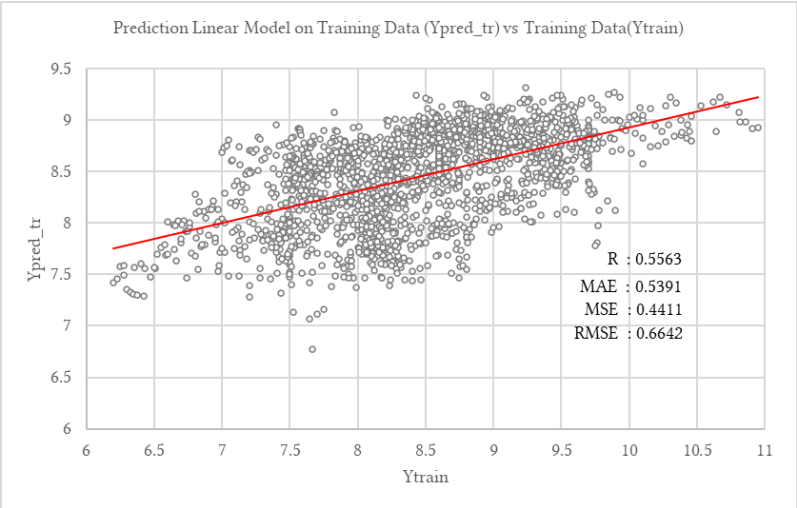

Figure 4: Plot prediction vs actual training data in linear model

with the sulfur content in the Electric Furnace Matte. Higher furnace roof temperature will reduce the sulfur content in Electric Furnace Matte. It is indicating that SO2 are released into furnace stack with the increasing of roof temperature. The increasing of cascade sulfur setting is conducted to increase sulfur content in Electric Furnace Matte. However the model shows different direction. Sulfur content in Electric Furnace Matte was decreased when the cascade setting was increased. Meanwhile for the cobalt content in the slag, coal feed rate and exit gas temperature kiln have positive coefficient correlation indicating that increasing the cobalt, coal feed rate and kiln exit gas temperature will also increasing the sulfur content in Electric Furnace Matte.

Performances of regression model based on the training data were evaluated. The sulfur content predicted based on model and actual dataset were compare and plot. Figure 4 shows the correlation plot between Ytrain (sulfur content in Electric Furnace Matte on the training data) and the Ypred_tr(sulfur content in Electric Furnace Matte based on prediction) based on linear model. The correlation coefficient is 0.5563 with MAE 0.5391, MSE 0.4411 and RMSE 0.6642. The low correlation of the prediction and the actual value gave indication that there are other parameter that could impact the sulfur content in matte and the correlation might not linear.

The test data are used further to evaluate the linear model with new dataset unknown to the model. For the test data, the model showed correlation coefficient 0.5571, MAE 0.5344, MSE 0.4255 and RMSE 0.6523. The model performance in the test data is similar with performance of the model in training data. The test data and predicted data based on linear model are plot in Figure 5.

Based on the predictor that has been selected by refined linear model, support vector regression model are developed. Performances of the model were evaluated both for the training data and the test data. The model gives R 0.8336, MAE 0.3186, MSE 0.1955 and RMSE 0.4421 for the training data. For the test data it gives R 0.8027. MAE 0.3592, MSE 0.2266 and RMSE 0.4760. The model performance are improved with support vector machine regression. Further evaluation on the support vector regression model

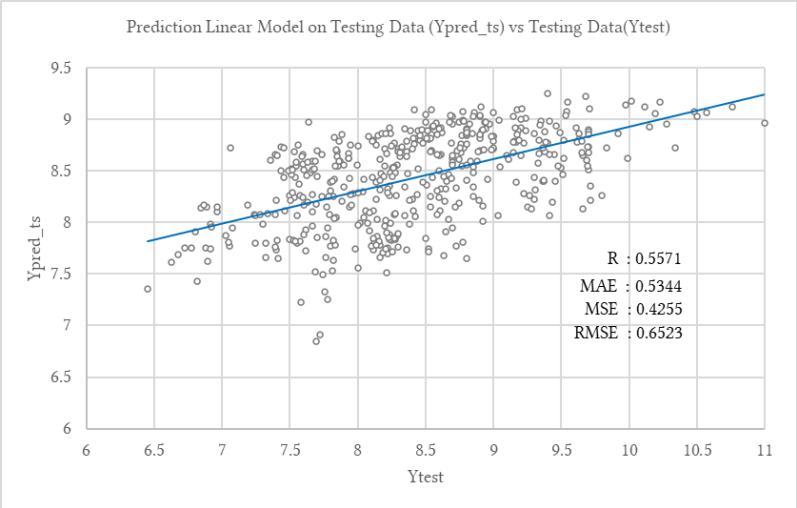

Figure 5: Plot prediction vs actual testing data in linear model

are made with cross validation. Other predictor that might improve the model are selected. The variables selected are as below:

- Kiln operating condition : sulfur cascade (x61_k5_cascade_sulphur), ore feed rate (x38_k5_ore), coal rate (x41_k5_rate_coal) and kiln exit gas temperature x45_k5_temp_exit)
- Furnace operating condition : draft pressure between electrode 2-3 (x27_f4_pres_el23), roof temperature 1B (x36_f4_temp_roof_c1b), roof temperature 2B (x32_f4_temp_roof_c2b), roof temperature 5B (x37_f4_temp_roof_c5b) and roof temperature 6B (x34_f4_temp_roof_c6b)
- Electric furnace slag composition : sulfur content (X01_EFS_S), iron content (X04_EFS_Fe), Al2O3 content (X05_EFS_Al2O3) , and ratio SM (X08_EFS_SM)
- Electric furnace feed composition : volatile matter (X17_EFF_VM), Fe reduction (X18_EFF_FER) and Ni reduction (X21_EFF_NIR)

Temperature at thermocouples #6 and temperature at thermocouple #10 were removed from support vector regression model since the predictors did not improve the model performance. For the furnace operating condition, the furnace draft pressure 2-3 was added. The draft pressure in furnace will determine the amount of gas suction from furnace and could impact on the SO2 that goes to the stack. The roof temperature in feed chute 1B, 2B, 5B and 6B are added. For the slag composition, several element were added as predictors : sulfur, iron and Al2O3 content. The composition of furnace feed also added to the model, volatile matter, Fe reduction and Ni reduction. The selection of the predictors are made based on cross validation, the predictors that can improve model performance are added while other predictors that not improve the model are removed. There are total 17 predictors involved in the support vector regression model.

The performances of support vector regression model on the train data can be seen in Figure 6. Meanwhile the run chart plot of testing data and prediction based on support vector regression can be seen in Figure 7. The coefficient correlation is 0.9542, MAE 0.1593, MSE 0.0608 dan RMSE 0.2466. Model performances were improved a lot with cross validation of the parameter.

The support vector regression model based on train data were applied on the test data to evaluate the model on unknown dataset. The model shows coefficient correlation 0.9408, MAE 0.1936, MSE 0.0762 and RMSE 0.2760. The performance of the model on test almost the same with performance on training set data. Figure 8 and Figure 9 show the plot of the prediction and testing data in scatter plot and also running chart. The model prediction can follow the testing data trend.

To linear model was also developed for this 17 predictors for fair comparison since the previous linear model only involved 11 predictors. The performance of linear model on training data with 17 predictors can provide coefficient correlation 0.5843, MAE 0.5247, MSE 0.4207 and RMSE 0.6486. While on the test data the model give coefficient correlation 0.5676, MAE 0.5294, MSE 0.4186 and RMSE 0.6470. However the p-value of 5 predictors are above 0.05 indicating that the coefficient of those predictors in the linear regression model is 0. Those 5 parameters are sulfur content in furnace slag, iron content in furnace slag, Al_2O_3 content in slag, Ni reduction in furnace feed and the pressure inside furnace between electrode 2 and electrode 3.

We can see that the model performance did not improve significant even though the number of predictors were added a lot. This show the limitation of linear model to predict the sulfur content in Electric Furnace Matte and the benefit of using support vector regression for prediction model.

5 CONCLUSION AND RECOMMENDATION

Machine learning method has been used to predict sulfur content in Electric Furnace Matte in nickel matte smelter. Two models were developed and compared; the linear regression multi variable and

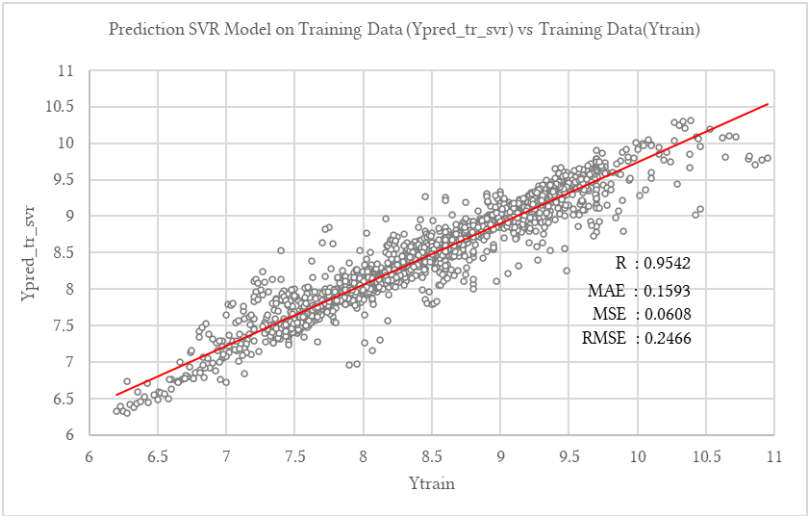

Figure 6: Plot prediction vs actual training data in SVR model

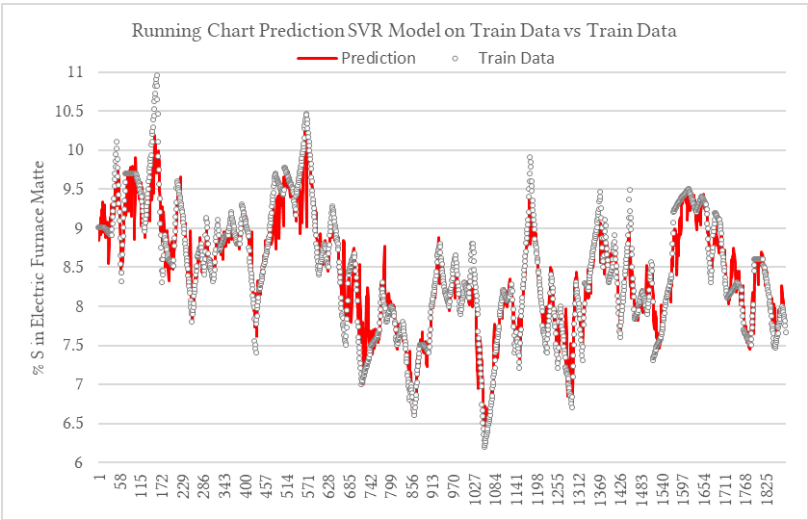

Figure 7: Run chart prediction vs actual training data in SVR model

the support vector regression model. The support vector regression model performs much better than the linear multi variable regression. With this approach, the sulfur content in Electric Furnace Matte can be predict using the available data both operating condition in kiln, furnace and the chemistry composition of the furnace feed and furnace slag. The prediction model can be utilized as decision support system in controlling sulfur content in Electric Furnace Matte.

The approach however has several limitation. The operating data and chemistry composition data are not available in the same scale. The operating data available all the time from the field sensor while the chemistry composition data available in certain period at different scale as well. The integration of the data required data imputation or deletion that might affect the model performance. The other approach of data integration could be the future research on this topic.

Other research opportunity is to continue the research on other kiln-furnace circuit in PTVI. The other prediction model can be developed as well for the similar process for example the prediction of carbon content in furnace feed and the prediction of iron content in slag or ratio silica magnesia content in furnace slag. For the process safety, the approach can be applied in the prediction of process safety event like high pressure event in furnace or molten metal leakage at the electric furnace wall.

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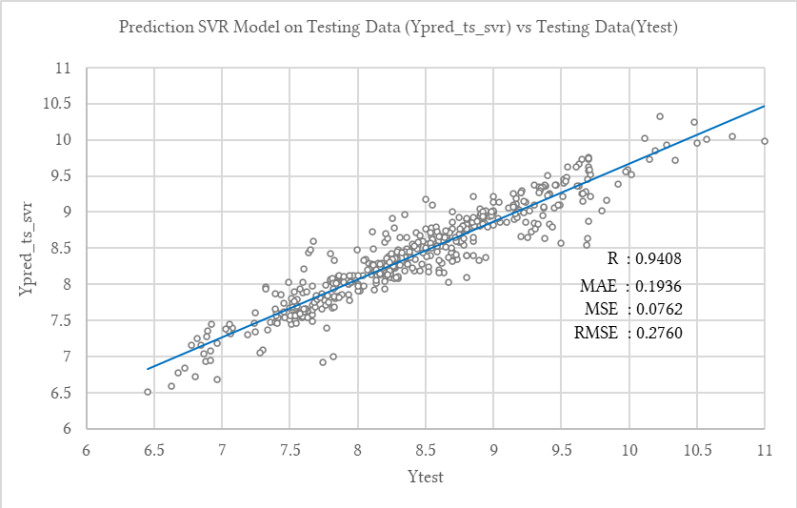

Figure 8: Plot prediction vs actual testing data in SVR model

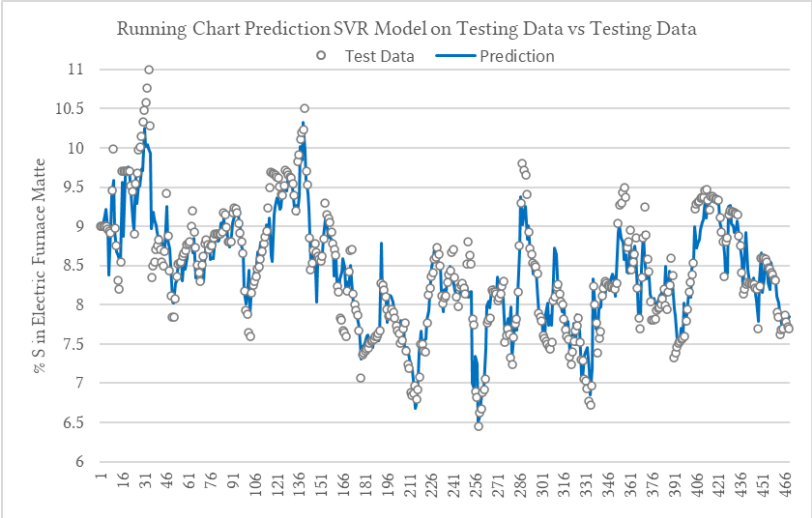

Figure 9: Run chart prediction vs actual testing data in SVR model

REFERENCES

[1] Mudd, G.V. 2010. Global trend and environmental issues in nickle mining:Sulfide versus laterites. *Ore Geologi Reviews 38, 9-26.* http://dx.doi.org/10.1016/j.oregeorev.2010.05.003

[2] Winjobi, O., Kelly, J.C and Dai, Q. 2022. *Life-cycle analysis, by global region, of automotive lithium-ion nickel manganese cobalt batteries of varying nickel content"*, Sustainable Materials and Technologies, Vol. 32. https://doi.org/10.1016/j.susmat.2022.e00415

[3] Luo, Y., Wei, H., Tang, L., Huang, Y., Wang, Z., He., Z., Yan, C., Mao, J., Dai, K. and Zheng, J. 2022. Nickel-rich and cobalt-free layered oxide cathode materials for lithium ion batteries. *Energy Storage material, Vol. 50,* 274-307. https://doi.org/10.1016/j.ensm.2022.05.019

[4] https://nickelinstitute.org/en/about-nickel-and-its-applications/nickel-in-batteries/

[5] Doyle, C. 2004. The step required to meet production target at PT Inco Indonesia : A new innovative business strategy, *International Laterite Nickel Symposium*

[6] Crundwell, F.K., Moats, M.S., Ramachandran, V., Robinson, T.G. and Davenport, W.G. 2011. *Extractive Metallurgy of Nickel, Cobalt and Platinum-Group Metal.* Elsevier, UK

[7] Murphy, K.P. 2012. *Machine Learning : A probabilistic perspective.* The MIT Press, Cambridge, London, England

[8] Bertolini, M., Mezzogori, D., Neroni, M. and Zammori, F. 2021. *Machine Learning for Industrial Application : A comprehensive Literature Review.* Expert System With Application, 175. https://doi.org/10.1016/j.eswa.2021.114820

[9] McCoy, J.T. and Auret, L. 2019. *Machine learning application in mineral processing : A review*, Mineral Engineering, Vol. 132, 95-109. https://doi.org/10.1016/j.mineng.2018.12.004

[10] Mallick, A, Dhara, S. and Rath, S. 2019. *Application of machine learning algortithms for prediction of sinter machine productivity,* Machine Learning with Application, 2021, 6. https://doi.org/10.1016/j.mlwa.2021.100186

[11] Ge, Z., Song, Z., Ding, S.X. and Huang, B. 2017. Data Mining and Analytics in the Process Industry : The Role of Machine Learning, *Special Section on Data-Driven Monitoring, Fault Diagnosis and Control of Cyber-Physical Systems, Vol. 5.* https://doi.org/10.1109/ACCESS.2017.2756872

[12] Imtiaz, S.A and Shah, S.L. 2008. Treatment of Missing Values In Process Data Analysis, *The Canadian Journal of Chemical, Vol. 86, 840.* https://doi.org/10.1002/cjce.20099

[13] Rubin, D.B. 1976. Inference and missing data, *Biometrika Trust, Oxford University Press.* https://doi.org/10.1002/j.2333-8504.1975.tb01053.x</bib>

Sustainable Manufacturing Performance Enhancement Using Lean Competitive Strategy: A Case Study in Plastic Molding Industry

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ABSTRACT

The regulation, market pressure, and company image have motivated the company to consider sustainability issues in their production process. A lean production competitive strategy enables the company to identify waste and improper activities during production, thus enhancing the sustainable manufacturing performance (Sustainability Index). This research aims to provide empirical evidence of how the lean production competitive strategy improves the Sustainability Index (SI). A case study was conducted in an Indonesian plastic molding company. This research consists of three main phases. The first phase defines the Sustainable Value Stream Mapping (SVSM) and SI indicators, the second phase focuses on creating current SVSM and measuring SI, and the third phase focuses on the results achieved after improvement. There are 2360.89 seconds, 1450.86 seconds, 3.2%, and 1.06 seconds time reductions for non-value added activities, necessary non-value-added activities, process cycle efficiency, and cycle time, respectively. Moreover, there are improvements of 0.05, 0.02, 2.14, and 0.21 for the economic, social, environmental, and overall SI. The results of this research can guide practitioners in implementing a lean production competitive strategy to enhance the SI. For academicians, the research provides empirical evidence of the positive impact of lean production competitive strategy making a company more sustainable.

CCS CONCEPTS

• **Applied computing**; • **Operations research**; • **Industry and manufacturing**; • **Command and control**;

KEYWORDS

Sustainable manufacturing, Lean strategy, Sustainable value stream mapping, Sustainability index, Sustainability performance

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1 INTRODUCTION

The regulation [1], market competitiveness [2], and corporate image [3] are among the primary motivations driving manufacturing companies to take into account sustainability issues in their daily production processes. Lean production is one of the sustainable competitive manufacturing strategies [4]. The main objective of sustainable lean production is to adopt lean management tools and procedures for enhancing sustainability performance [5].

Sustainable lean needs a modified traditional Value Steam Mapping (VSM) to identify waste and improper activity during production. Previous studies have proposed various modified traditional VSMs related to economic, environmental, and social factors. Sari et al. [6] developed a simple sustainable VSM to measure the contribution of the lean production system and enhance the sustainability index that an Indonesian car manufacturer validated. The sustainable VSM consists of 13 indicators concerning economic, environmental, and social perspectives. This study provides evidence that sustainable lean enables a company to create competitive advantages while addressing environmental and social factors; therefore Sustainability Index (SI) is getting better. Cherrafi et al. [7] developed an instrument measuring the readiness level of a company to start implementing a sustainable lean management system. This instrument was validated in four companies. This assessment enables a company to map out the potential barriers to sustainable lean implementation; therefore, the appropriate actions can be taken.
Some of the previous studies focused more on green issues. Abreu et al. [8] stated that the main objective of lean green initiatives is to enhance productivity by reducing waste and negative environmental impact. Teixeira et al. [9] proposed a conceptual model concerning the relationship between lean and green to enhance sustainability. The results stated that lean and green have the common

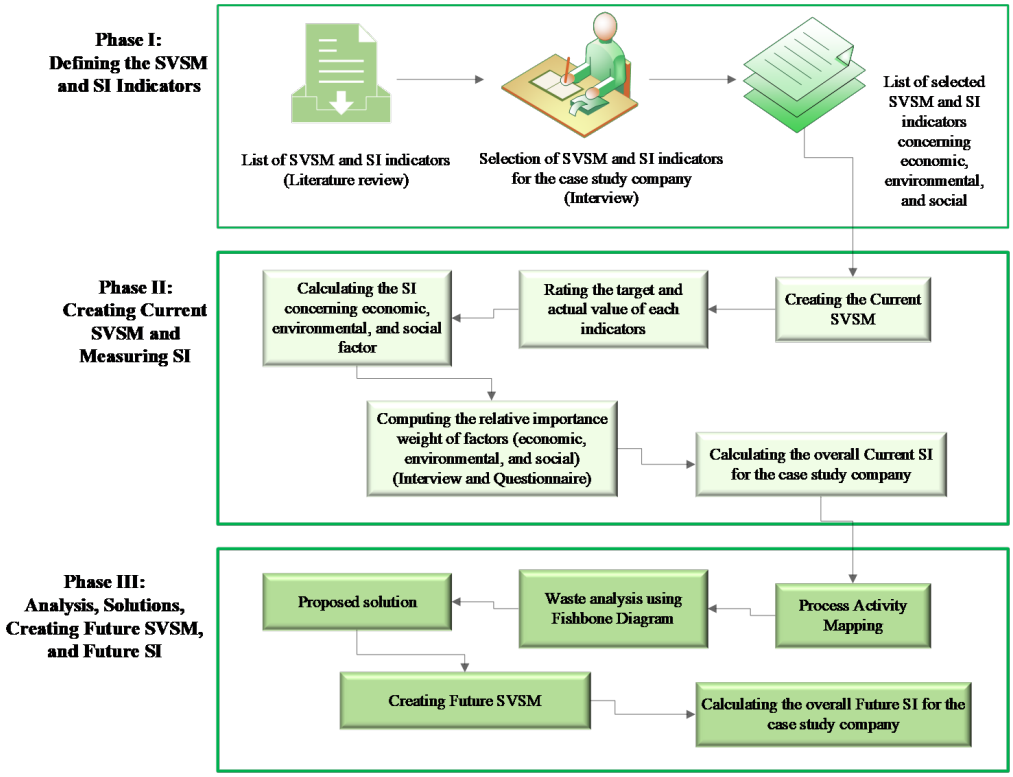

Figure 1: Research Approaches

objective of reducing waste; thus, it is one of the crucial contributors to sustainable development. Wen et al. [10] developed an Energi Value Mapping (EVM), which focused on modeling energy loss, analyzing energy loss using lean principles, and determining the improvement strategies. This EVM was validated in China's die-casting plant, achieving 6.17% energy reduction, 5% energy utilization enhancement, and 4.8%-time utilization enhancement. Hartini et al. [11] combined the concept of lean and green to develop green VSM for an Indonesian wooden furniture company focused on time, quality, material, energy, and waste. This research proved that wooden furniture companies have more than 50% of potential waste that can be reused as raw material for derivative products such as a coffee table. Therefore, it provides evidence that green VSM improves material efficiency (economic benefit) and reduces the use of virgin wood logs (environmental benefit).

2 RESEARCH APPROACHES

This section describes the processes and lean tools used to enhance sustainable manufacturing performance, as shown in Figure 1. There are three main phases: Phase I focuses on defining the SVSM and SI indicators; Phase II focuses on creating current SVSM and measuring current SI; Phase III focuses on waste analysis, proposed solutions, creating future SVSM, and measuring future SI.

3 RESULTS AND DISCUSSION

This section presents the results and discussion of each phase.

Table 1: The Selected Sustainable VSM and SI Indicators

Indicators	References
Economic	
Time	[12]
Material	[11]
Environmental	
Energy	[10]
Recycle	[5]
Overproduction	Authors' contribution
Social	
Noise	[9]
Health and safety	[6]

3.1 Sustainable VSM and SI Indicators

This phase begins with identifying the sustainable VSM and SI indicators based on previous studies. Next, the interviews were conducted to determine the appropriate indicators for the case study company. The output of this phase is the list of selected economic, environmental, and social indicators, as presented in Table 1.

3.2 Current Sustainable VSM and SI

This phase focuses on creating current sustainable VSM and measuring current SI. The first phase focuses on developing current

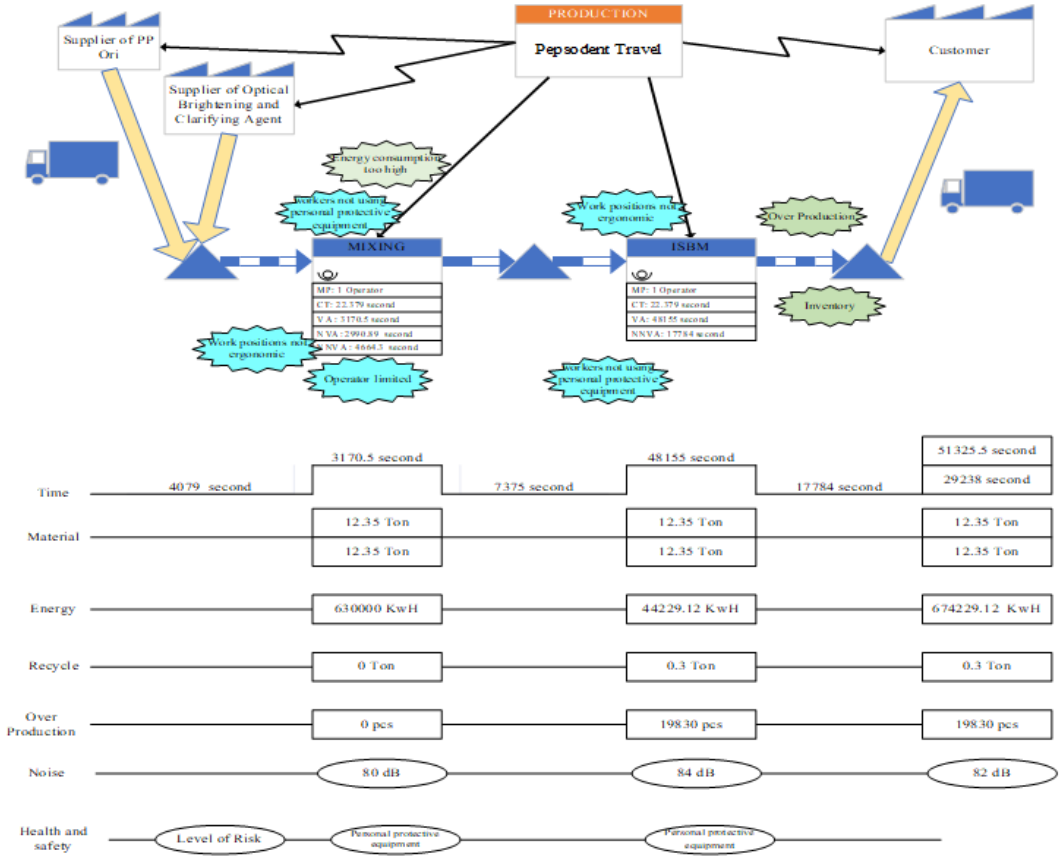

Figure 2: Current Sustainable VSM

sustainable VSM, as presented in Figure 2. Current sustainable VSM is a lean manufacturing approach to see the material flow and information about overall product production from raw material to delivery to customers.

Based on Figure 2, sustainable VSM consists of three primary pieces of information. Firstly, the information related to time, Value Added time (VA), Non-Value Added (NVA) time, and Necessary Non-Value Added (NNVA) time. Secondly, Kaizen Burst gives information related to problems in the production process, i.e., energy consumption too high, workers not using personal protective equipment, work positions not ergonomic, operator limited, overproduction, and inventory. Thirdly, dashboard realization for each indicator. For example, the noise level at the Mixing and ISBM departments were 80 and 84, respectively. Based on the international benchmark, the maximum noise level allowed is 85 dB. Therefore, there is no problem related to this indicator.

The second phase focuses on measuring the current SI where the step and formulation adopted from Sari et al. [6]. SI measures how much the change value of each indicator supports the company to be more sustainable [13]. SI values for the case study company were 85%, 45%, and 378 for economic, social, and environmental, respectively. The overall SI was 101% which needs 1.01 times more effort concerning time and cost than exiting conditions to be sustainable

3.3 Analysis, Solution, Future Sustainable VSM, and SI

This phase focuses on waste analysis using Process Activity Mapping (Table 2) following Fishbone Diagram. After waste analysis, this study proposed solutions for the case study company as presented in Table 3. Next, this study created the future sustainable VSM and measured future SI. Finally, the improvement achieved by implementing the sustainable lean competitive strategy can be seen in Table 4 and Table 5.

Table 4 shows the time reduction obtained in the production process after the proposed solutions. It can be seen that the NVA value decreases by 2360.9 seconds, and the PCE value increases by around 3.2%. It revealed that improvement using a lean production competitive strategy has a good effect on the production process by time reduction. Table 5 shows that the overall SI of the case study company is improved very significantly from 101% to 80%. The improvement is expected to be achieved by implementing the proposed solution (Table 3). This study proposed six solutions

Table 2: Waste analysis

PEPSODENT TRAVEL PRODUCTS												
Work Station Area	Work Station Area	Process	Value			Waste						
			VA	NNVA	NVA	OPROD	D	I	T	W	M	IP
Warehouse of raw materials	1	Plastic raw material (PP Ori) inspection		510.02								✓
	2	Inspection of Optical Brightening and Clarifying Agent Dyes		328.82						✓		
	3	Transfer of raw materials and dyes to the mixing area		1824.02								✓
Mixing Area	4	Mixing Machine Set-Up		1416.58								✓
	5	Mixing Process	3170.53									
	6	Inspection of the results of the mixing process		584.86								✓
	7	Transfer the results of mixing to the pallet			725.71				✓			
	8	Transfer of pallet to Trolley			1959.7				✓			
Injection Stretc Blow Molding (Machine 6)	9	Transferring the results of mixing from the pallet to the machine 6			305.48				✓			
	10	Set up the machine		3799.31								✓
	11	Product Printing	48155.1			✓	✓	✓				
	12	Product Inspection		1139.13								✓
	13	Packaging		7549.49								✓
	14	Movement of finished goods to the warehouse		9095.38								✓

Note: OPROD: Over Production; D: Defect; I: Inventory; W: Waiting; T: Transportation; M: Motion, IP: Inappropriate Processing

Table 3: Proposed Solutions

Problems	Proposed Solutions	Chance for Implementation
Waste overproduction Waste inventory	Bill of Material Tables & Structures	Possible to do
Waste defect	Maintenance of the machine before and after the production process [14]	Adjusted/ aligned by expert advise
Waste waiting	Gantt Chart	Possible to do
Less tidy production floor	5S	Maybe, but to realize it requires a long time, and a sense of responsibility from each worker
Energy use is too extensive	Reducing the use of mixing machines and ISBM by calculating the use of raw materials appropriately	Possible to do
The work position is not ergonomic	Seat design for operators	Possible but require a small fee to make an ergonomic chair

to overcome seven main problems concerning economic, social, and environmental factors. For example, over-production and inventory (economic) due to inaccurate calculation of raw materials can be overcome by creating a Bill of Material Tables and Structures. Waste defect (economic) can be reduced by executing planned maintenance. Planned maintenance leads to machine accuracy in producing high-quality products [15]. Concerning social factors, this study suggests redesigning an ergonomic seat for operators. Concerning energy (environmental), this study suggests reducing the use of mixing machines and ISBM by appropriately calculating the use of raw materials

Table 4: Time Improvement

Time	Before Improvement	After Improvement	Variance
VA (second)	51325.62	51325.62	0
NVA (second)	2990.89	630	2360.89
NNVA (second)	26247.61	24796.75	1450.86
PCE (%)	63.7	66.9	-3.2
Cycle Time (second)	22.38	21.32	1.06

Table 5: The Selected Sustainable VSM and SI Indicators

Sustainability Index	Before Improvement	After Improvement	Variance
Economic	0.85	0.80	0.05
Social	0.45	0.43	0.02
Environment	3.78	1.64	2.14
Overall	1.01	0.8	0.21

4 CONCLUSIONS

This study has twofold benefits for academicians and practitioners. From an academic perspective, this study revealed the positive relationship between lean production strategy implementation and sustainable manufacturing performance. There are improvements related to time and SI by implementing proposed solutions. The NVA value decreases by 2360.9 seconds and the overall SI value by 0.21. Moreover, this research will guide practitioners in implementing a lean production competitive strategy to become more sustainable.

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REFERENCES

[1] Dharmendra Hariyani and Sanjeev Mishra. 2022. Drivers for the adoption of integrated sustainable green Lean Six Sigma Agile manufacturing system (ISGLSAMS) and research directions. Cleaner Engineering and Technology, 7, 100449, 1-30. https://doi.org/10.1016/j.clet.2022.100449

[2] Iveline Anne Marie, Emelia Sari and Cut Alda Lika. 2020. Enhancing sustainable maintenance performance using lean competitive manufacturing strategy: a case study in steel company. Solid State Technology, 63(6), 902-917.

[3] Emelia Sari, Azanizawati Ma'aram, Awaluddin Mohamed Shaharoun, Abdoulmohammad Gholamzadeh Chofreh, Feybi Ariani Goni, Jiří Jaromír Klemeš, Iveline Anne Marie and Docki Saraswati. 2021. Measuring sustainable cleaner maintenance hierarchical contributions of the car manufacturing industry. Journal of Cleaner Production, 312, 127717, 1-16. https://doi.org/10.1016/j.jclepro.2021.127717

[4] Ibrahim Garbie. 2016. Sustainability in Manufacturing Enterprises: Concepts, Analyses and Assessments for Industry 4.0, Springer Nature, Switzerland.

[5] Rodrigo Rodriguez Delgadillo, Khaled Medini and Thorsten. 2022. A DMAIC framework to improve quality and sustainability in additive manufacturing—A case study. Sustainability, 14(1), 581, 1-18. https://doi,org/10.3390/su14010581

[6] Emelia Sari, Iveline A. Marie, Erika Erika, Abdoulmohammad G. Chofreh, Feybi A. Goni, Jiří Jaromír Klemeš, Masoomeh Zeinalnezhad. 2021. Lean sustainable competitive manufacturing strategy assessment: a case study in the Indonesian car manufacturing company. Chemical Engineering Transactions, 88, 859-864 DOI:10.3303/CET2188143

[7] Anass Cherrafi, Jose Arturo Garza-Reyes, Amine Belhadi, Sachin S. Kamble, Jamal Elbaz. 2021. A readiness self-assessment model for implementing green lean initiatives. Journal of Cleaner Production, 309, 127401, 1-17. https://doi.org/10.1016/j.jclepro.2021.127401

[8] M. Florentina Abreu, Anabela C. Alves, Francisco Moreira. 2017. Lean-green models for eco-efficient and sustainable production. Energy, 137, 846-853. https://doi.org/10.1016/j.energy.2017.04.016

[9] P. Teixeira, J.C. Sá, F.J.G. Silva, L.P. Ferreira, G. Santos, P. Fontoura. 2021. Connecting lean and green with sustainability towards a conceptual model. Journal of Cleaner Production, 322, 129047, 1-16. https://doi.org/10.1016/j.jclepro.2021.129047

[10] Xuanhao Wen, Huajun Cao, Bernard Hon, Erheng Chen, Hongcheng Li. 2021. Energy value mapping: A novel lean method to integrate energy efficiency into production management. Energy, 217, 119353, 1-15. https://doi.org/10.1016/j.energy.2020.119353

[11] S. Hartini, P.A. Wicaksono, M.D Rizal and M. Hamdi. 2021. Integration lean manufacturing and 6R to reduce wood waste in furniture company toward circular economy. IOP Conference Series: Materials Science and Engineering, 1072(1), 012067, 1-12. https://doi.org/10.1088/1757-899x/1072/1/012067

[12] Hamed Gholami, Norhazrina Jamil, Muhamad Zameri Mat Saman, Dalia Streimikiene, Safian Sharif, Norhayati Zakuan. 2021. The application of green lean six sigma. Business Strategy and the Environment, 30(4), 1913-1931. https://doi.org/10.1002/bse.2724

[13] Ibrahim Garbie. 2016. Sustainability in Manufacturing Enterprises: Concepts, Analyses and Assessments for Industry 4.0. Springer Nature, Switzerland.

[14] Emelia Sari, Awaluddin Mohamed Shaharoun, Azanizawati Ma'aram, A. Mohd Yazid. 2015. Sustainable maintenance performance measures: a pilot survey in Malaysian automotive companies. Procedia CIRP, 26, 443-448.

[15] Maria Holgado, Marco Macchi, Stephen Evans. 2020. Exploring the impacts and contributions of maintenance function for sustainable manufacturing. International Journal of Production Research, 58 (23), 7292–7310. https://doi.org/10.1080/00207543.2020.1808257

INTEGRATED COST AND VALUE STREAM IN CRANKCASE PRODUCTION (CP)

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ABSTRACT

Crankcase Production (CP) is a company engaged in manufacturing, one of which produces one component of the engine motor unit, namely the crankcase component. In the production process, there are still various indications of waste that cause a decrease in the efficiency and effectiveness of the production process. One of the biggest problems is defects, with a percentage of defects above 5%. Therefore, it is necessary to optimize the process of the crankcase to increase the effectiveness and efficiency of production. This study aims to eliminate waste in the production line of the crankcase by implementing the lean manufacturing concept. The lean manufacturing method used is the Waste Assessment Model (WAM) to distinguish waste in the manufacturing process. The integrated cost value stream introduces cost lines that can help facilitate decision-making. Based on the results of waste identification, the 3 largest wastes were found, namely defects, inventory, and transportation. There are 2 alternative improvements to overcome this waste, namely by changing the jig tool and changing the push-to-pull method. The results show that defect waste decreased to an average of 4.8%, the total value added cost decreased by 1%, total non-value added cost decreased by 55%.

CCS CONCEPTS

• **General and reference**; • **Document types**; • **General conference proceedings**;

KEYWORDS

Lean manufacturing, waste assessment model, activity-based costing, integrated cost value stream

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1 INTRODUCTION

Companies in manufacturing can be said to be highly developed and competitive. Companies are required to continue to make continuous improvements to the company's performance. Effective and efficient production has the potential to deliver products that are not only of high quality but also competitive. The Crankcase Production (CP) is a company engaged in manufacturing, one of which produces one component of the engine motor unit, namely the crankcase component. Crankcase products are the product with the highest demand at the moment, which is around 15.500 sets per month. The crankcase production process, which is continuous, is currently not running in a balanced manner following the assembly process. Meanwhile, to fulfill the current demand for crankcases, which is more than the average, which is 15,500 sets per month, this is done by working overtime.

Indication waste is found in the manufacturing process in Crankcase Production (CP), with a relatively large number of defective products. Based on these data, part of the crankcase looks quite high in its reject value, which exceeds the 5% limit of the company's stipulation. It can be said that the efficiency of the production process on parts crankcase has not been reached.

Lean manufacturing is a suitable method for optimizing process and performance production systems due to can measure, identify, analyze and provide improvement solutions and performance improvements in a comprehensive manner. Something the model is needed in the waste identification process. Some of the assessment tools to find out the waste problem is the used Waste Assessment Model (WAM).

To simplify decision-making, cost analysis use Activity Based Costing (ABC) is carried out on value streams. It is used in the identification of the various components of cost as well as perform an overall relative contribution analysis of those costs.

2 LITERATURE REVIEW

2.1 Lean Concept

In terms of language or terminology, the word "lean" means the arrangement of activities or solutions to reduce not only waste but also non-value added (NVA) operations and improve value-added operations (Wee, H. M and Simon Wu, 2009).According to Liker (2004) lean manufacturing is the optimal method for producing goods through the elimination of waste (waste), reducing costs, and increasing the ability of workers.

2.2 Seven Waste Concept

The concept of a lean approach in principle is the elimination of inefficiency (waste). This definition of waste can also mean all

activities without added value to the company's output. There are seven types of waste (seven waste s) according to Hines & Taylor (2000), namely: overproduction, defect (reject), inventory, process, transportation, waiting/idle, motion.

2.3 Waste Assessment Model (WAM)

The waste Assessment Model (WAM) is a model used to simplify the process of finding waste problems and identifying them to eliminate waste (Rawabdeh, 2005). This WAM provides an overview of the relationship between seven types of waste. In the waste assessment model method, data processing will be carried out in the form of seven waste relationships, Waste Relationship Matrix (WRM), and Waste Assessment Questionnaire (WAQ).

A waste Relationship is a tool used to reduce the amount of waste that affects each other between types to make the production process run optimally.

The waste Relationship Matrix (WRM) is a matrix used to analyze the measurement criteria. Columns in the matrix show the types of waste that are affected by other types of waste. The rows in the matrix indicate the impact of one type of waste on the other six types of waste. The diagonal side of the matrix has the highest relation value

Waste Assessment Questionnaire (WAQ) is used as a tool to identify and allocate waste types in a company's production line (Rawabdeh, 2005). This assessment is in the form of a questionnaire consisting of 68 different questions.

2.4 Value Stream Mapping (VSM)

The term value stream is translated as an activity that can be said to be special in the supply chain system, which will play a role in the design process, ordering process, and also in determining the specific value of the product (Hines and Taylor, 2000). Besides that, VSM is also used in the process of identifying which activities have value added and which activities are non-value added in the manufacturing industry.

2.5 Value Stream Mapping Tools

In VSM there are seven types of detailed mapping tools that are commonly used (Hines and). Rich, 1997), that is: Process Activity Mapping (PAM), Supply Chain Response Matrix (SCRM), Quality Filter Mapping (QFM), Production Variety Funnel (PVF), Decision Point Analysis (DPA), Demand Amplification Mapping (DAM), Physical Structure (PS).

2.6 Cost Integrated Value Stream Mapping

Cost Integrated Value Stream integrates VSM and cost aspects that function to produce a cost line to facilitate management in making decisions. The process of Redesigning VSM with this cost aspect is very helpful for management in refocusing on improvement areas.

Cost analysis is done by building an integration between the cost line in VSM and the timeline that already exists in VSM. Cost line helps simplify management when making decisions. The formulas below are what you need in cost analysis:

$$\text{Value added activity cost} = mi + CTi\left(\frac{Mi + Li}{3600}\right) \tag{1}$$

$$\text{mi} = 0 \ \ \text{(when no material is added to the activity)}$$

$$\text{Non value added activity cost} = \text{hi} \times \text{li} \tag{2}$$

$$\text{Total value added cost} = \sum_{\text{n}=1}^{\text{n}} \text{mi} + \text{CTi}\left(\frac{\text{Mi} + \text{Li}}{3600}\right) \tag{3}$$

$$\text{Total non} - \text{value added cost} = \sum_{i=1}^{n+1} hi \times li \tag{4}$$

Information :
CT = Cycle Time
M = Machine *rate* per hour
L = Operator *rate* per hour
m = material cost
I = Inventory (raw material, work in process (WIP), finished goods)
h = Holding cost inventory

3 METHODS

This research is descriptive research that contains a description and interpretation of a condition, development of opinion, an ongoing process, and a causal relationship. Data collection is the stage of collecting information on the total of the entire population in the study. This study uses secondary data sources.
To obtain data, the researchers used several techniques, namely:

- Interview

Data collected through the interview process must meet the following criteria:

- Holding a functional position in the company (managers, supervisors, and employees) in the production division
- Have worked in the company for at least 3 years.
- D3 education or above.
- Company documentation
- Company documentation is needed as research supporting data, where the data source comes from documents, records, or archives owned by the production division. The data needed in this study is a general description of the company, production process activities, material flow, cycle manufacturing processes, and production workforce needs.

The steps in this research are as follows :

- Data Collection Stage
- At this stage is the collection of data needed during research where the data will then be processed to find out the best solution to the problem. The following data needs in research like Data regarding material flow, data related to production activities, data cycle time of each manufacturing process, data on labor requirements for each manufacturing process, machine hour rate, labor hour rate, material cost, amount of stockpile, Inventory holding cost, defect data in PPM
- Data Processing
- Data is processed after the data is collected at this stage, through literature studies and direct observations in the field. Data processing includes the following steps:
- Creation of Current State Value Stream Mapping
- It takes the data flow of the production process and leads time production activity to create a VSM.
- Identification of Current Cost Integrated State Map

Table 1: Machining Crank Case Process Inventory

No	Activity	Inventory	
1	Raw Material from Platform to OP1	400	pcs
2	WIP between OP1 and OP2	0	pcs
3	WIP between OP2 and OP3	0	pcs
4	WIP between OP3 and OP4	0	pcs
5	WIP between OP4 and check air micro and TC Cleaning	0	pcs
6	WIP between check air micro and TC Cleaning	0	pcs
7	WIP between Leak test and final appearance check	0	pcs
8	WIP between final appearance check and finish goods	200	pcs
	TOTAL INVENTORY	**600**	**pcs**

- Data that has been collected is used to design the current cost-integrated value stream map. There is data information flow, production, cost line, and timeline. The data are processed as follows: total value stream inventory, WIP calculation, total product cycle time, total value stream lead time, the total value added cost & non-value added cost
- Waste Identification and Measurement
- Waste Assessment model used for identification of *waste* using interviews and distribution of questionnaires with weighting to related sections
- Data Analysis
- At this stage, an analysis of the results is carried out on the collected data and process previously. Data analysis includes analysis of current and future VSM, as well as comparing the current and future cost integrated value streams. Data analysis produces interpretation and discussion to answer research problems
- Idea Recommendation Improvement
- This stage is an activity of analyzing the results of processing and drawing conclusions from the answers to the formulation of the problem

4 RESULTS

4.1 Identification of Current Cost Integrated State Map Lean

Table 1 follows the inventory of crankcase parts in the form of raw material, WIP, or finished goods from the finish of the casting process until delivery :

Table 2 is the result of calculating the cycle time for each machining crankcase manufacturing process:

Before calculating the total value added cost, we must first find out the machine data rate, operator rate, and material costs. The following Table 3 is the engine data rate in the manufacture of the crankcase

The labor hour rate at Crankcase Production Company (CPC) is Rp. 27,630. Data quantity and price of materials to make crankcase shown in Table 4 as follows

Table 2: Cycle Time for Machining Crank Case Process

No	Activity	Cycle Time (Second)
1	OP1	63
2	OP2	78
3	OP3	66
4	OP4	84
5	Check Air Micro & TC Cleaning	138
6	Leak Test	180
7	Appearance Check	54
TOTAL PRODUCT CYCLE TIME		**663**

Table 3: Machining Crank Case Process Machine Rate

Machine name	Rate /hour	
OP1	Rp.	368,000
OP2	Rp.	468,000
OP3	Rp.	234,000
OP4	Rp.	682,000
Check Air Micro and TC Cleanning	Rp.	122,000
Leak Test	Rp.	110,000
Appearance Check	Rp.	12,000

Table 4: Raw Material Prices for Machining Crank Case Process

Material name	Unit	Price	
Raw parts crank case	1	Rp.	247,000
Raw Material Supplier	3	Rp.	62,000
Total		**Rp.**	**309,000**

Table 5: Raw Material Prices for Machining Crank Case Process

No	Proses	Value Added Cost	
1	OP1	Rp.	315,924
2	OP2	Rp.	10,739
3	OP3	Rp.	4,797
4	OP4	Rp.	11,827
5	Check Air Micro & TC Cleaning	Rp.	5,736
6	Leak Test	Rp.	6,882
7	Appearance Check	Rp.	594
TOTAL VALUE ADDED COST		**Rp.**	**356,498**

So that the following table 5 is the value added cost data obtained Before calculating the total non-*value added cost*, we must first find out the holding cost data inventory, after that, we can calculate the non-value added cost like table 6 below.

Table 6: Raw Material Prices for Machining Crank Case Process

No	*Inventory* Name	*Inventory Holding Cost*
1	*Holding Cost Inventory* OP1	Rp. 14,000
2	Holding Cost Inventory OP2	Rp. -
3	Holding Cost Inventory OP3	Rp. -
4	Holding Cost Inventory OP4	Rp. -
5	Holding Cost Inventory Check Air Micro & TC Cleaning	Rp. -
6	Holding Cost Inventory Leak Test	Rp. -
7	Holding Cost Inventory Appearance Check	Rp. -
8	Holding Cost Inventory Finish Good	Rp. 10,000
	TOTAL NON-VALUE ADDED	Rp. **24,000**

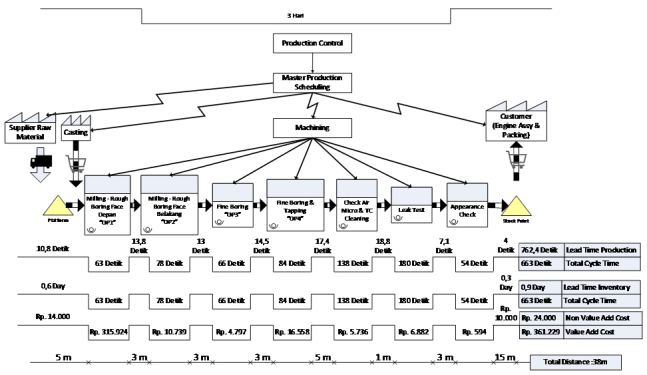

Figure 1: Current Cost Integrated State Map

Detail Value Stream Mapping Machining Crank Case can see in figure 1.

4.2 Identification Waste

Table 7 The following is the waste matrix value for the machining crankcase production process.

The waste value from WRM is used as the initial WAQ value according to there are 68 questions from the questionnaire. Question with "From", explains the type of waste as a trigger for other types of waste based on WRM. Questions with "To", explain each current waste as a result of influencing other types of waste. And the final result for the identification of waste can see in Table 8.

From the results of the questionnaire above, it was found that the 3 biggest wastes are defects, inventory, and transportation. Furthermore, VALSAT will be selected based on the results of weighting the waste.

4.3 Value Stream Analysis Tools (VALSAT)

4.3.1 Process Activity Mapping (PAM). The machining crankcase production process consists of 27 sequential work steps The details of the portion of each type of activity are shown in Table 9 below. From Table 9 above, there are 5 activities in the value-added category and 22 activities non-value added percentage that must be lowered. PAM machining crankcase results show the total time for the production of 1 product is 762 seconds with details for each activity type in table 10 follows.

From Table 10 Can be seen the time for activities value added of 429 seconds (56% total time), and non-value added of 44% need to be reduced so that it can be more provide added value for customers.

4.3.2 Supply Chain Response Matrix (SCRM). The tabulation of the results of calculating lead time and inventory is shown in table 11 below.

SCRM analysis found a total time of 4.17 days machining crankcase g un a reach product order. The total cumulative days of physical stock is 3.32 days (the average per day required for materials in the order fulfillment system). Days physical stock which is highly

Table 7: Waste Matrix Value Machining Crank Case

F/T	O	I	D	M	T	P	W	Score	%
O	10	10	4	6	8	0	4	42	15.56%
I	2	10	6	6	8	0	0	32	11.85%
D	4	10	10	10	8	0	8	50	18.52%
M	0	2	8	10	0	8	8	36	13.33%
T	6	6	6	8	10	0	6	42	15.56%
P	6	4	8	6	0	10	6	40	14.81%
W	2	10	6	0	0	0	10	28	10.37%
Score	30	52	48	46	34	18	42	270	100.0%
%	11.11%	19.26%	17.78%	17.04%	12.59%	6.67%	15.56%	100.0%	

Table 8: Calculation of Waste Ranking

	O	I	D	M	T	P	W
Final Result (Yj Final)	24.33	33.19	46.13	25.89	27.29	9.44	18.42
The final result (%)	13%	18%	25%	14%	15%	5%	10%
Ranking	5	2	1	4	3	7	6

Table 9: Summary of PAM Activities

Activity	Operation	Transport	Inspection	Storage	delay
Amount	5	13	2	1	6
Percentage	19%	48%	7%	4%	22%

Table 10: Summary of PAM Percentage

Activity	Operation	Transport	Inspection	Storage	delay
Amount	429	51,7	234	4	43,7
Percentage	56%	7%	31%	1%	6%

Table 11: Calculation of SCRM Machining Crank Case

No	**Items**	**Days Physical Stock**	**Lead Times**	**Cumulative Days Physical Stock**	**Cumulative Lead Times**
1	Raw Material Storage Area (F/G Casting)	1.54	0.56	1.54	0.56
2	Production Process Area (WIP Machining)	1	0.01	2.54	0.57
3	Finished Product Storage Area (F/G Machining)	0.78	0.28	3.32	0.85
				Total	**4.17**

correlated with the length of inventory accumulation in the order fulfillment system chain.

4.3.3 Quality Filter Mapping (QFM). Quality Filter Mapping (QFM) is a tool for identifying quality problems (defects) along the supply chain. The following table 12 is the average reject part in the last 3 months (January 2020 to March 2020).

Table 12: Reject Data Machine Machining Crank Case

No	Process	Reject Rate
1	OP1	0.5%
2	OP2	0.2%
3	OP3	1.0%
4	OP4	5.0%
5	Check Air Micro & TC Cleaning	0.0%
6	Leak Test	0.0%
7	Appearance Check	0.0%
8	Delivery	0.0%

Based on the QFM machining crankcase above, it can be seen that the largest waste defect/reject is in the OP4 area with a reject rate of 5%.

4.4 Idea Improvement

4.4.1 Changing the Jig Tool. Improvements to the Jig Tool design on the OP4 engine can reduce defects (reject parts) which also have an impact on :

- The process flow is getting smoother, it can minimize waste in the form of waiting.
- Output production increases, so there is no need for inventory waste in the raw material area can be removed.

Modification of the OP4 machine tool jig is carried out in the Engineering department through technical studies and trials.

Before the repair, the tool design that is large enough does not make a perfect hole in the tool's taper-shaped material. It is necessary to improve the tool design so that the drilling power on the workpiece increases by changing the shape, position, and grip area. So that the new tool design applied in April 2021 has a grip area of 15 mm . position _ drilling from the inside of the workpiece as

Figure 2: Design Change of Jig Tool Machining Crank Case

well as the contact area in the form of a hole effective. Reject _ OP4 machine process parts machining production line has decreased as follows.

4.4.2 Changing Push Method to Pull. Sales forecasting is a management guideline to calculate the volume of material purchases and the level of inventory so stocking out is avoided. Just In Time production system developed by the company Japan is only to produce type requests consumer goods, the amount needed, when needed. Philosophy JIT emphasizes total management operations with the use of resources (raw materials, parts, personnel, and facilities) to the extent needed to increase productivity and minimize waste. JI T is supported by the principle of sustainable production flow d with condition cooperation of every part of the production process with components other.

A pull system is a production process to minimize inventory. If the JIT principle is applied to the production system, then the product is produced according to the number of requests at the time needed. The production control system earlier (push system) relies on the production schedule of the manufacturing process in each department. But by using the pull system method, the production schedule must be in sync starting from customer requests to the availability of raw materials. Table 14 The following is a comparison of stock inventory before repair and after repair.

Furthermore, changing the method from push to pull also has an impact on reducing transportation activities. Where previously each department had to send parts to customers (customers here are the next process, namely assembly parts) now from customers who take parts to each shop. So that in machining production there is only a transport process for taking the finished casting raw material. As for finishing good machining, it is enough to just prepare it at the stock point, where later the team from the assembly part will take the part.

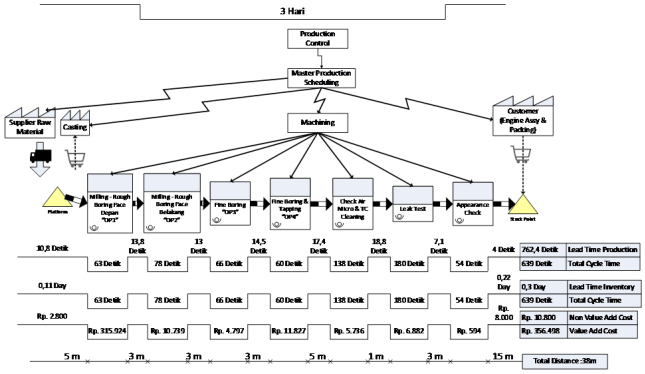

Figure 3: Proposed Integrated Value Stream Mapping

Based on the improvements above, it can be seen that the waste defect can be reduced to an average of 4.8% by replacing the jig tool on the OP4 machine. In addition, inventory waste and transportation waste can be reduced by changing the method from a push system to a pull system. In terms of inventory can be reduced to 360 pcs / day. And also in terms of transportation can reduce 1 manpower.

The results showed that production lead time could decrease by 0.6 days or decrease by 60%, cycle time could decrease by 24 seconds or 4%, the total value added cost decreased by Rp. 4.7311 or 1%, and the total non-value added cost decreased by Rp. 13,200 or 55%.

5 CONCLUSION

The conclusions obtained from this study include the following:

The Waste Assessment Model (WAM) method produces 3 (three) categories of waste The main production line of machining crankcases is defect/ reject parts (25%), unnecessary inventory (18%), and transportation (15%).

Waste arises as a result of several problems. Process OP4 (fine boring and tapping) causes it, right? reject parts highest in machining crank production line case, reject rate of 0.5%. Furthermore, waste unnecessary inventory, in the area of raw materials for the machining production line, obtained days of physical stock of 1.54 days. Stock raw materials excess and their absorption are not optimal due to limited machining production capacity. And the last is transportation waste. This transportation waste is due to the layout of the casting and machining processes in different buildings

Table 13: Reject Data Conditions Before and After Repair

Condition	Period	Production Quantity (pcs)	Number of Rejects (pcs)	Reject Rate (pcs)
Before Repair	Jan	15,700	894.9	5.7%
	Feb	16,200	1101.6	6.80%
	Mar	15,950	972.95	6.10%
After Repair	April	16,100	772.8	4.80%
	May	16,200	793.8	4.90%
	Jun	15,500	744	4.80%

Table 14: Inventory Conditions Before and After Repair

No	Activity	Inventory			
		Before		After	
1	Finished good casting and OP1	400	pcs	80	pcs
2	WIP between OP1 and OP2	0	pcs	0	pcs
3	WIP between OP2 and OP3	0	pcs	0	pcs
4	WIP between OP3 and OP4	0	pcs	0	pcs
5	WIP between OP4 and check air micro and TC Cleaning	0	pcs	0	pcs
6	WIP between TC Cleaning and Leak Test	0	pcs	0	pcs
7	WIP between Leak test and final appearance check	0	pcs	0	pcs
8	WIP between final appearance check and delivery	200	pcs	160	pcs
	TOTAL INVENTORY	**600**	**pcs**	**240**	**pcs**

Recommendations for overcoming waste are to modify the jig tool and change the push method to pull

Improvements made can reduce total value added cost from Rp. 361,229 to Rp. 356,498. Reduction of total non-value added cost from Rp. 24,000 to Rp.10,800Display Computer codes can be inserted using "ComputerCode" style.

REFERENCES

[1] Goriwondo, William M., Samson Mhlanga, and Alphonce Marecha. (2011), "*Use of The Value Stream Mapping Tool for Waste Reduction in Manufacturing (Case Study for Bread Manufacturing in Zimbabwe)*", Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management.

[2] Hines, P., and D. Taylor. (2000) Going Lean, Lean Enterprise Research Center, Cardiff Business School.

[3] Hines, P. and Rich, N. (1997), "The seven value stream mapping tools", International Journal of Operations & Production Management, Vol. 17 No. 1, pp. 46-64.

[4] Liker, J. K. (2004). The Toyota Way. United States: Mc Graw hill.

[5] Mc. Williams, Douglas L and Edem G. Tetteh. (2008), *"Value-Stream Mapping to Improve Productivity in Transmission Case Machining"*, Proceedings of the 2008 Industrial Engineering Research Conference J. Fowler and S. Mason. Eds.

[6] Rawabdeh, I. (2005), *"A Model for the assessment of waste in job shop environments"*, International Journal of Operations & Production Management, Vol. 25 No. 8, pp. 800-822.

[7] SdRother, M., & Shook, J. (2003). *Learning to See, Value Stream Mapping to Create Value and Eliminate Muda.* Cambridge: The Lean Enterprise Institute, Inc.

[8] Wee, H.M and Simon Wu. (2009), *"Lean supply chain and its effect on product cost and quality: a case study on Ford Motor Company"*, Supply Chain Management: An International Journal 14/5 (2009) 335–341.

Mapping of Digital Transformation Readiness, Benefits, and Barriers in Indonesian Steel Manufacturing

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ABSTRACT

Indonesian steel manufacturing sector has proven able to survive and even thrive during the COVID-19 pandemic. Its post-pandemic potential is also very large, considering that Indonesia's steel consumption per capita is the lowest in ASEAN. However, the highly volatile business situation and competition mean that it needs to reduce process costs, reduce processing time, and increase productivity; all of which could potentially be achieved by digital transformation. However, there is very limited research on digital transformation in Indonesian steel manufacturing. This research aims to map the readiness, potential benefit, and barriers to digital transformation in Indonesian steel manufacturing using MICMAC matrix method, with validation and verification carried out directly by experts involved in decision-making process on several steel manufacturing entities in Indonesia. Result of this study shown that to prepare digital transformation readiness, Indonesian steel manufacturing should emphasize its effort on preparing strategy and leadership, investment for industry 4.0, innovation policy, competency development, connectivity, and cyber security. The main benefits that should be pursued first are the capability of monitoring in real time and assisting in communication and data flow; whereas the main barrier that should be taken care of first is preparing its organizational change.

CCS CONCEPTS

• **Applied computing** → Operations research; Industry and manufacturing; Operations research; Decision analysis; Multi-criterion optimization and decision-making.

KEYWORDS

Steel Manufacturing, Digital Transformation, Readiness, Benefit, Barrier, MICMAC

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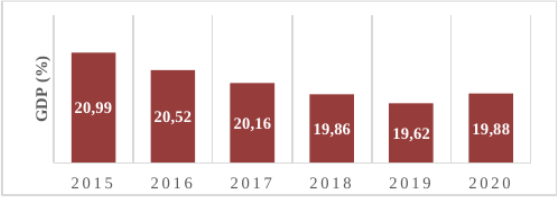

Figure 1: Contribution of the manufacturing industry to Indonesian economy [1]–[3]

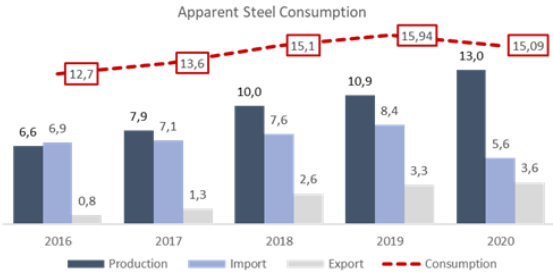

Figure 2: Indonesian steel production, import, export, and consumption figures [8]

1 INTRODUCTION

Indonesian manufacturing industry contribution to Indonesia's Gross Domestic Product (GDP) tends to decline in the last five years as illustrated on Figure 1. One of the possible causes is the low performance of Indonesian industry, shown by Indonesia's poor Competitive Industrial Performance (CIP) due to the low intensity of industrialization and technology implementation as presented on Table 1.

Indonesia is the country with the lowest steel consumption among other ASEAN countries as presented in Table 2. In addition to having a large area and an archipelago, the large population also causes the low value of this steel consumption. On the other hand, the low consumption of steel in Indonesia can also be seen as a potential for a large increase in consumption in the future.

Globally in 2019 the steel industry value chain contributed USD 2,901 billion and employed 95.9 million jobs [7]. Whereas in Indonesia, As illustrated in Figure 2, steel production throughout 2020

Table 1: CIP Index of Indonesia compared to several high industrial countries [4]

Country	Industrial Performance		Industrialization Intensity		Technology Implementation	
	Index	Rank	Index	Rank	Medium	High
Germany	0,47	1	0,68	6	52,7%	21,2%
Korea	0,35	3	0,79	3	40,2%	34,1%
Japan	0,34	5	0,65	10	64,0%	16,7%
Indonesia	0,08	39	0,51	21	24,2%	4,5%

Table 2: Steel Consumption of ASEAN Countries [5], [6]

Country	Steel Consumption Per Capita				
	2015	2016	2017	2018	2019
Indonesia	45	49	52	55	59
Filipina	86	97	101	104	109
Thailand	242	279	278	285	292
Vietnam	199	241	267	291	314
Malaysia	321	323	323	322	321
Singapura	725	503	502	502	502
ASEAN (avg.)	125	138	144	150	157

was able to increase by 19.6% compared to 2019. This proves that domestic steel products could replace imported products which in total decreased by more than 33%. This condition was followed by an increase in the value of steel exports to reach 6.5%.

Regrettably, according to IISIA Indonesian steel industry utilization is only around 50% year after year [9], very far from good utilization standard for steel manufacturing with is 80% [10]. External threats such as competition with imported steel [10] and price volatility [11] always pressures the industry to reduce process costs, reduce processing time, and increase productivity; all of which could potentially be achieved by digital transformation.

Digital transformation has proven to be able to build long-term resilience and increase manufacturing industry profits [12]. Besides cost reduction and profit increase, there are other benefits that can be obtained such as readiness to face various changes (agility), accelerated order fulfillment (speed to market), processing flexibility, increased productivity, and operational stability [12], [13].

However, there is very limited research available on digital transformation in steel manufacturing industry, especially in Indonesia. With the limited information available, the high cost also carried a huge risk that might hinder Indonesian steel manufacturing to pursue digital transformation.

Therefore, this research aims to map the readiness, potential benefit, and barriers to digital transformation in the steel manufacturing industry. Hopefully this research could provide a rough directive of what Indonesian steel manufacturing industry should prepare before considering digital transformation.

2 LITERATURE STUDY

2.1 Digital Transformation Readiness

The Indonesian government has set INDI 4.0 (Indonesian Industry 4.0 Readiness Index) as a standard reference for measuring the level

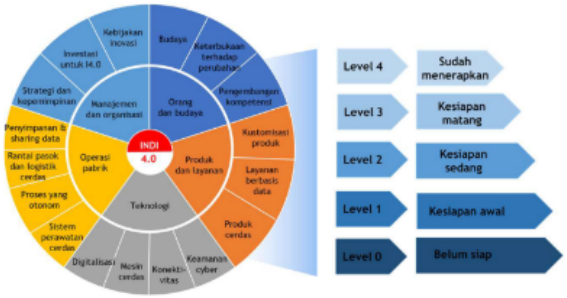

Figure 3: Indonesian Industry 4.0 Readiness Index [14]

Table 3: Digital Transformation Benefits

No	Benefits	References
1	Cost reduction	[12], [16]–[18]
2	Increase competitiveness	[16]–[19]
3	Real time monitoring	[16], [17]
4	New business model creation	[16], [17], [19]
5	Value chain optimization	[16], [17]
6	Communication & data flow	[16], [17]
7	Process efficiency improvement	[12], [16], [17], [19]
8	Process time reduction	[12], [16]–[18]
9	Quality improvement	[16]–[18]
10	Planning assistance	[16], [17]

of readiness for digital transformation, covering five pillars of Industry 4.0 as illustrated in Figure 3 (a) Management and Organization, (b) People and Culture, (c) Products and Services, (d) Technology, (e) Plant Operations [15]. INDI 4.0 is carried out by means of an independent assessment by filling out a questionnaire comprises of 33 questions: (a) company information (7 questions), (b) INDI 4.0 Pillars (23 questions) and (c) digital transformation challenges (3 questions) [14].

2.2 Digital Transformation Benefits

The potential benefits of digital transformation observed from various related references could be seen on Table 3.

2.3 Digital Transformation Barriers

The potential barriers of digital transformation observed from various related references could be seen on Table 4.

Table 4: Digital Transformation Barriers

No	Barriers	References
1	Requires organizational change	[16], [17], [19], [20]
2	Requires huge investment	[16], [17], [19], [21]
3	Limited available resources	[16], [17], [20]
4	Requires competency development	[16], [17], [20], [21]
5	Reluctance to change	[16], [19], [20]
6	Potential employee reduction	[16], [17], [20]
7	Potential cybersecurity breach	[16], [17], [19], [21]
8	Requires advanced IT tools	[16], [17], [21]
9	Requires data integration	[16], [17]
10	Poor existing data quality	[16], [19]
11	Might disrupts operations	[16]
12	Might requires a long time	[16], [17]

2.4 MICMAC

MICMAC (Matriced' Impacts Croises-Multipication Applique' and Classment) was first introduced by Gobet in 1994 as part of "strategic foresight" which focuses on analysis of development scenarios [22]. MICMAC uses an approach that relies on analytical thinking through a systematic solution to a problem. The stages of MICMAC are: (a) reviewing the scope of the problem and the system by involving experts through Focus Group Discussions (FGD), (b) Incorporating the results of the first stage into the MICMAC module (software developed by LIPSOR) to identify variables and (c) Confirming the results in the second FGD [23]. MICMAC will result in enrichment of information, understanding of the system, and identification of key drivers that change the system.

3 METHODOLOGY

3.1 Research Design

This research employed an exploratory descriptive research design with using expert judgment or perception in describing, explaining, and interpreting related phenomenon using Focus Group Discussion (FGD). The agreed values will be analyzed using MICMAC to map various related indicators of digital transformation readiness, benefits, and barriers for steel manufacturing industry.

3.2 Data and Information

The type of data used in this research is qualitative primary and secondary data. The indicators obtained from previous research will be the basis for identifying variables related to steel manufacturing digital transformation. The indicators obtained from the literature review in Table 3 and Table 4 are classified into 5 Pillars and 17 Fields of INDI 4.0 as shown on Table 5, Table 6, and Table 7, then validated by experts using FGD.

3.3 Data Collection

The data used to build the strategy model are primary and secondary data. Primary data were obtained from FGD with experts. Secondary data obtained from literature study to obtain a theoretical basis related to this research. Literature studies are carried out by reviewing reference books and the latest scientific literature.

Table 5: Digital Transformation Readiness Indicators

INDI Pillar	Digital Transformation Readiness Indicators	
Management and Organization	Strategy and Leadership	KMO1
	Investment for Industry 4.0	KMO2
	Innovation policy	KMO3
People and Culture	Competency development	KOB1
	Organization Culture	KOB2
	Openness to change	KOB3
Products and Services	Data-driven service	KPL1
	Smart product	KPL2
	Product customization	KPL3
Technology	Connectivity	KTK1
	Cyber security	KTK2
	Intelligent machine/system	KTK3
	Digitalization	KTK4
Plant Operations	Data storage and sharing	KOP1
	Smart supply chain and logistics	KOP2
	Autonomous process	KOP3
	Intelligent maintenance system	KOP4

Table 6: Digital Transformation Benefit Indicators

INDI Pillar	Digital Transformation Benefit Indicators	
Management and Organization	Cost reduction	MMO1
	Increase competitiveness	MMO2
	Real time monitoring	MMO3
Products and Services	New business model creation	MPL1
	Value chain optimization	MPL2
Technology	Communication & data flow	MTK1
Plant Operations	Process efficiency improvement	MOP1
	Process time reduction	MOP2
	Quality improvement	MOP3
	Planning assistance	MOP4

Table 7: Digital Transformation Barrier Indicators

INDI Pillar	Digital Transformation Barrier Indicators	
Management and Organization	Requires organizational change	PMO1
	Requires huge investment	PMO2
	Long return of investment	PMO3
People and Culture	Limited human resource	POB1
	Requires competency development	POB2
	Reluctance to change	POB3
	Potential employee reduction	POB4
Technology	Potential cybersecurity breach	PTK1
	Requires advanced IT tools	PTK2
	Requires data integration	PTK3
	Poor existing data quality	PTK4
Plant Operations	Might disrupts operations	POP1
	Might requires a long time	POP2

Table 8: Steel Manufacturing Experts Qualification

Institution	Amount	Qualification
Industry	1	Experienced as top management in steel manufacturing industry for more than 5 years
Association	2	Actively participating in the Association's technical committee, experienced as mid management in steel manufacturing industry for more than 10 years
Government	1	Actively participating in regulation of steel Manufacturing industry policies for more than 5 years
Researcher	1	Actively participating in research related to the steel manufacturing industry for more than 10 years

3.4 Sample and Population

Population of this study are experts related to Indonesian steel manufacturing industry. Only those who are considered experts relevant to the research should be considered [24]. To reflect a balanced point of view and ensure validity, 5 experts directly involved with decision-making process related to Indonesian steel manufacturing were selected according to qualifications shown in Table 8.

3.5 MICMAC Relational Matrix

The indicators collected shall be used as the basis for making MICMAC questionnaire in FGD with experts. The result shall be depicted into relational matrix then analyzed to map the relationship between indicators and their dependencies to identify key indicators. These indicators are grouped into 6 dimensions according to the 6 Pillars of INDI 4.0. Experts will determine the dependence of the relationship between these indicators by filling out a questionnaire with a scale of 0 (no relationship); 1 (weak relationship); 2 (average); 3 (strong); P (cannot be determined by agreement).

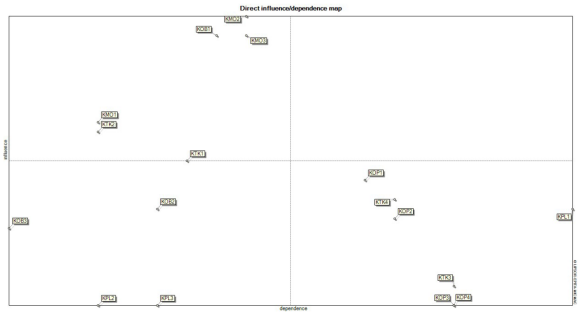

Figure 4: Digital Transformation Readiness Mapping

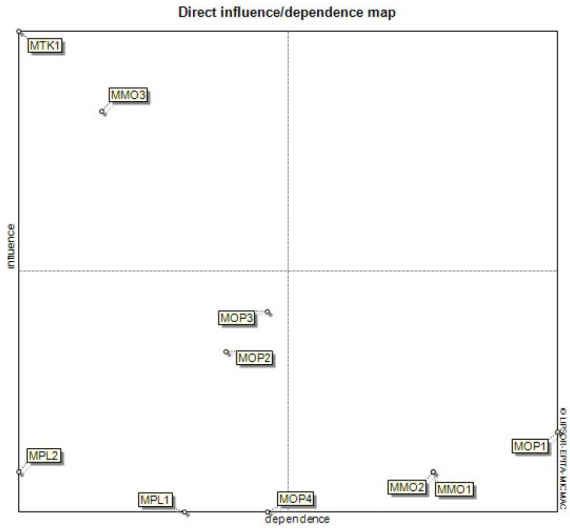

Figure 5: Digital Transformation Benefits Mapping

4 RESULT AND DISCUSSION

The result of FGD with experts shall be presented as a matrix in Table 9, Table 10, and Table 11. Those matrices shall be used for MICMAC analysis with Lipsor, resulting in MICMAC indicators mapping in Figure 4, Figure 5, and Figure 6.

4.1 Digital Transformation Readiness

Analysis of Table 9 with MICMAC resulted in a mapping of indicator shown in Figure 4. Six indicators are in the driver variable quadrant, namely strategy and leadership (KMO1), investment for industry 4.0 (KMO2), innovation policy (KMO3), competency development (KMO4), connectivity (KTK1), and cyber security (KTK2).

4.2 Digital Transformation Benefits

Analysis of Table 10 with MICMAC resulted in a mapping of indicator shown in Figure 5. Two indicators are in the driver variable

Table 9: Digital Transformation Readiness Matrix

	KMO1	KMO2	KMO3	KOB1	KOB2	KOB3	KPL1	KPL2	KPL3	KTK1	KTK2	KTK3	KTK4	KOP1	KOP2	KOP3	KOP4
KMO1	0	3	3	2	2	1	2	P	P	P	P	P	2	2	P	P	P
KMO2	2	0	2	2	2	P	2	2	2	2	2	2	2	2	2	2	2
KMO3	P	2	0	2	2	P	2	2	2	2	2	2	2	2	2	2	2
KOB1	2	2	2	0	P	P	2	2	2	2	2	2	2	2	2	2	2
KOB2	2	2	2	2	0	2	P	P	P	P	P	P	P	P	P	P	P
KOB3	P	2	2	2	2	0	P	P	P	P	P	P	P	P	P	P	P
KPL1	0	0	0	0	0	0	0	P	P	P	P	2	2	P	2	2	2
KPL2	0	0	0	0	0	0	0	0	P	P	P	P	P	P	0	0	0
KPL3	0	0	0	0	0	0	P	P	0	0	0	0	0	0	0	0	0
KTK1	0	0	0	0	0	0	3	P	P	0	P	2	2	2	2	2	2
KTK2	0	0	0	0	0	0	3	P	P	3	0	2	2	2	2	2	2
KTK3	0	0	0	0	0	0	2	P	P	0	0	0	0	P	P	P	P
KTK4	0	0	0	0	0	0	P	P	P	P	P	2	0	3	2	2	2
KOP1	0	0	0	0	0	0	3	P	P	0	0	2	2	0	2	2	2
KOP2	0	0	0	0	0	0	3	0	2	0	0	P	P	P	0	2	2
KOP3	0	0	0	0	0	0	0	0	0	0	0	P	P	P	0	0	0
KOP4	0	0	0	0	0	0	0	0	0	0	0	P	P	P	0	0	0

Table 10: Digital Transformation Benefits Matrix

	MMO1	MMO2	MMO3	MPL1	MPL2	MTK1	MOP1	MOP2	MOP3	MOP4
MMO1	0	3	0	0	0	0	0	0	0	0
MMO2	3	0	0	0	0	0	0	0	0	0
MMO3	P	P	0	0	P	P	3	3	3	3
MPL1	0	2	0	0	0	0	0	0	0	0
MPL2	P	1	0	2	0	0	0	0	0	0
MTK1	P	P	2	2	P	0	2	2	3	3
MOP1	3	1	0	P	0	0	0	0	0	P
MOP2	2	1	0	P	0	0	3	0	0	P
MOP3	2	2	0	P	0	0	3	0	0	0
MOP4	P	P	0	P	P	0	2	P	P	0

quadrant, namely real time monitoring (MMO3) and communication & data flow (MTK1).

4.3 Digital Transformation Barriers

Analysis of Table 11 with MICMAC resulted in a mapping of indicator shown in Figure 6. Only one indicator is in the driver variable quadrant, namely requires organizational change (PMO1).

4.4 Discussion

This research shown the driving indicators that should be emphasized among the various indicators related to digital transformation readiness, benefit, and barrier as shown in Table 12. This research also shown the INDI 4.0 Pillars that matters most to digital transformation effort in Indonesian steel manufacturing.

5 CONCLUSION

For an Indonesian steel manufacturing industry, to prepare for digital transformation readiness it should emphasize more effort

Table 11: Digital Transformation Barriers Matrix

	PMO1	PMO2	PMO3	POB1	POB2	POB3	POB4	PTK1	PTK2	PTK3	PTK4	POP1	POP2
PMO1	0	2	2	2	2	2	2	0	0	0	3	P	P
PMO2	P	0	P	2	2	P	P	2	3	2	2	0	0
PMO3	P	3	0	0	0	0	0	0	0	0	0	0	0
POB1	P	0	0	0	P	P	P	0	1	0	2	2	2
POB2	P	0	0	3	0	3	1	1	2	1	3	2	2
POB3	P	P	P	P	P	0	P	0	0	0	1	0	0
POB4	P	0	0	0	2	2	0	0	0	0	0	0	0
PTK1	0	0	0	0	2	0	0	0	2	1	0	0	0
PTK2	0	3	3	0	2	0	0	0	0	0	P	3	2
PTK3	0	2	1	P	P	0	0	0	2	0	P	2	1
PTK4	0	0	0	0	2	P	0	0	3	3	0	P	3
POP1	2	1	1	1	2	P	0	0	P	P	0	0	0
POP2	2	1	1	1	2	P	0	0	0	0	0	2	0

Table 12: Digital Transformation Driving Indicators

INDI Pillar	Digital Transformation Driving Indicators	
Management and Organization	Strategy and Leadership	Readiness
	Investment for Industry 4.0	Readiness
	Innovation policy	Readiness
	Real time monitoring	Benefit
	Requires organizational change	Barrier
People and Culture	Competency development	Readiness
Technology	Connectivity	Readiness
	Cyber security	Readiness
	Communication & data flow	Benefit

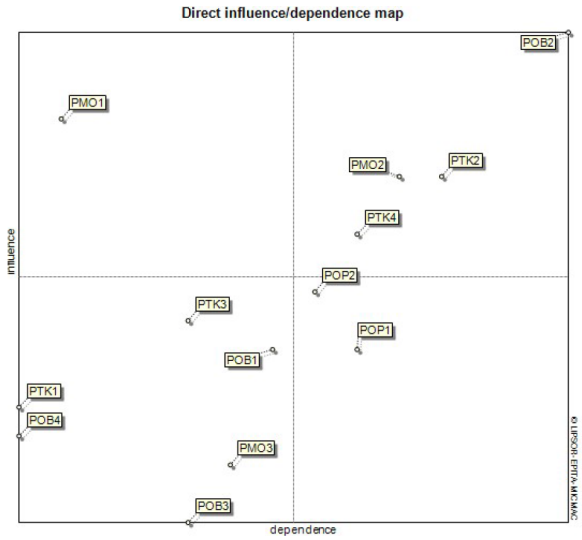

Figure 6: Digital Transformation Barriers Mapping

on INDI 4.0 Pillars that matters most which are: Management and Organization, People and Culture, and Technology. Specifically for preparing digital transformation readiness, it needs to prepare strategy and leadership, investment for industry 4.0, innovation policy, competency development, connectivity, and cyber security. The main benefits it should pursue first are the capability of monitoring in real time and assisting in communication and data flow; whereas the main barrier it should take care of first is to prepare organizational change. This study also served as a reminder that for a digital transformation to work, an Indonesian steel manufacturing should not only prepare the Technology, but also prepare the foundations of its organization which are its Management and Organization and its People and Culture.

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REFERENCES

[1] BPS, "National Income of Indonesia 2010-2014," BPS-STatistics Indonesia, Jakarta, 2014.
[2] BPS, "Pertumbuhan Ekonomi Indonesia Triwulan IV-2020," 2021. [Online]. Available: https://www.bps.go.id/pressrelease/2021/02/05/1811/ekonomi-indonesia-2020-turun-sebesar-2-07-persen--c-to-c-.html
[3] BPS, "Pertumbuhan Ekonomi Indonesia Triwulan III-2020," 2020.
[4] UNIDO, "Competitive Industrial Performance Report 2020," 2020. [Online]. Available: https://stat.unido.org/content/publications/competitive-industrial-performance-index-2020%253a-country-profiles
[5] World Steel Association, "World Steel in Figures 2020," 2020. [Online]. Available: http://www.worldsteel.org/wsif.php
[6] Worldsteel Association, "World Steel in Figures Report," 2021. [Online]. Available: https://www.worldsteel.org/en/dam/jcr:976723ed-74b3-47b4-92f6-81b6a452b86e/World%2520Steel%2520in%2520Figures%25202021.pdf
[7] Oxford Economics, "The Role of Steel Manufacturing in the Global Economy," 2019.
[8] IISIA, "Produksi Baja Nasional Tahun 2020 Meningkat |Update Konsumsi Baja Tahun 2020 dan Outlook 2021 | IISIA," *IISIA*, 2020. https://iisia.or.id/post/view/id/produksi-baja-nasional-tahun-2020-meningkat-di-tengah-penurunan-konsumsi-baja-selama-pandemi-covid19
[9] "IISIA: Baja Impor Bebani Utilisasi Industri Dalam Negeri - Ekonomi Bisnis.com." https://ekonomi.bisnis.com/read/20211103/257/1461633/iisia-baja-impor-bebani-utilisasi-industri-dalam-negeri (accessed Jul. 19, 2022).
[10] "Asosiasi Industri Keluhkan Serbuan Baja Impor, Utilisasi Pabrik dalam Negeri Hanya 50 Persen - Tribunnews.com." https://www.tribunnews.com/bisnis/2022/04/19/asosiasi-industri-keluhkan-serbuan-baja-impor-utilisasi-pabrik-dalam-negeri-hanya-50-persen (accessed Jul. 19, 2022).
[11] Steelbenchmarker, "Price History Tables and Charts USA China Western Europe World Export," 2021. Accessed: Dec. 11, 2021. [Online]. Available: www.steelbenchmarker.com
[12] K. Close, M. Grebe, P. Andersen, V. Khurana, M. R. Franke, and R. Kalthof, "The Digital Path To Business Resilience," 2020. Accessed: Apr. 19, 2021. [Online]. Available: https://www.bcg.com/en-sea/publications/2020/digital-path-to-business-resilience%0A//www.bcg.com/publications/2020/digital-path-to-business-resilience
[13] E. Tidhar, J. Siegman, and D. Paikowsky, "Building Industry 4.0 capabilities through collaborations with startups | Deloitte Insights," *Deliotte Insights*, 2018. https://www2.deloitte.com/us/en/insights/focus/industry-4-0/building-capabilities-through-collaborations-startups.html
[14] Kementrian Perindustrian RI, "Indonesia Industry 4.0 Readiness Index," *Kementrian Perindustrian RI*, pp. 1–23, 2018.
[15] N. T. Antara, "INDONESIA INDUSTRY 4.0 READINESS INDEX (INDI 4.0)," Cornell University Press, Jan. 2019. doi: 10.7591/9781501719370.
[16] R. Clancy, M. Ahern, D. O. Sullivan, and K. Bruton, "Systematic Mapping Study of Digitization and Analysis of Manufacturing Data," *Int. J. Ind. Syst. Eng.*, vol. 14, no. 9, pp. 717–731, 2020.
[17] M. Sony, "Pros and cons of implementing Industry 4.0 for the organizations: a review and synthesis of evidence," *Prod. Manuf. Res.*, vol. 8, no. 1, pp. 244–272, Jan. 2020, doi: 10.1080/21693277.2020.1781705.
[18] L. S. Dalenogare, G. B. Benitez, N. F. Ayala, and A. G. Frank, "The expected contribution of Industry 4.0 technologies for industrial performance," *Int. J. Prod. Econ.*, vol. 204, no. December 2017, pp. 383–394, Oct. 2018, doi: 10.1016/j.ijpe.2018.08.019.
[19] A. Ghadge, M. Er Kara, H. Moradlou, and M. Goswami, "The impact of Industry 4.0 implementation on supply chains," *J. Manuf. Technol. Manag.*, vol. 31, no. 4, pp. 669–686, Mar. 2020, doi: 10.1108/JMTM-10-2019-0368.
[20] J. M. Müller, "Assessing the barriers to Industry 4.0 implementation from a workers' perspective," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 2189–2194, 2019, doi: 10.1016/j.ifacol.2019.11.530.
[21] V. L. Da Silva, J. L. Kovaleski, R. N. Pagani, J. D. M. Silva, and A. Corsi, "Implementation of Industry 4.0 concept in companies: empirical evidences," *Int. J. Comput. Integr. Manuf.*, vol. 33, no. 4, pp. 325–342, Apr. 2020, doi: 10.1080/0951192X.2019.1699258.
[22] A. Fauzi, *Teknik analisis keberlanjutan.* Jakarta: PT Gramedia Pustaka Utama, 2019.
[23] M. del M. Delgado-Serrano, M. Ambrosio-Albalá, and F. Amador, "Exploration de l'analyse structurale prospective pour évaluer l'importance du développement rural territorial en Espagne et Nicaragua," *Cuad. Desarro. Rural*, vol. 12, no. 76, pp. 35–56, 2015, doi: 10.11144/Javeriana.cdr12-76.epsa.
[24] A. S. Rusydiana and A. Devi, *Analytic Network Process: Pengantar Teori dan Aplikasi.* 2013.

Enhancing Sustainable Performance using Lean Competitive Manufacturing Strategy: A Case Study at Motor Vehicle Battery Company

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ABSTRACT

PT GSB produces motor vehicle battery products. The problem experienced is that the production department cannot maintain its production achievements due to waste in the production process activities. Waste causes the production process to be inefficient as well as an increase in waste garbage. The purpose of this research is to analyze the results of mapping lean sustainable manufacturing and provide a proposed strategy to improve the performance of sustainable manufacturing in the company. The initial stage of the study was carried out by making sustainability value stream mapping (SVSM). The results of the analysis show that there is inappropriate processing, waiting, defect and transportation waste. Next is the calculation of the Sustainability Index (SI) and obtained a value of 144.3% which indicates the need for improvement to become a sustainable company. Based on the analysis using the Ishikawa Diagram, suggestions for improvement are given as strategy to improve sustainability performance in the company that is using a digital counter to facilitate the process of calculating the number of grids in the casting area, making SOP for setting up the pasting belt machine and utilizing the concept of Poka-yoke using iron plate to prevent operator errors when setting the machine.

KEYWORDS

lean, waste, SVSM, sustainability indicator, sustainability index

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1 INTRODUCTION

The global market has begun to increase awareness of sustainable manufacturing, as indicated by the proliferation of companies adopting a sustainable manufacturing paradigm and showing positive impacts [1]. The focus of the SDGs program is Responsible Consumption and Production, which is the 12th point of the 17 SDGs goals as one of the goals considered a priority for sustainable development [2].

The manufacturing sector is essential in supporting the successful implementation of the Sustainable Development Goals (SDGs) [3]. Regarding sustainable manufacturing, there are two types of competitive manufacturing strategies that can be carried out by organizations/companies, namely conventional strategies (related to cost, time and quality) and non-conventional strategies. Non-conventional competitive manufacturing strategies play an important role in evaluating manufacturing companies by optimizing the level of complexity, maximizing manufacturing leanness, manufacturing agility, remanufacturing, and recycling. Leanness, agility, remanufacturing, and recycling strategies are considered the domain of an organization/company's operational improvement strategy, and maximizing them will provide the potential for the company to grow [4].

Lean techniques can contribute to sustainable development [5]. Connecting with Lean Production Strategy, many researches related to the use of lean systems and lean tools has been widely carried out in various industries with the results of increasing production efficiency and output that helps improve company performance [6]. The goals of a lean system are to eliminate these eight types of waste, produce services and products only as needed, and to continuously improve the value-added benefits of operations [7]. The company's goal to reduce waste is to save on using resources and efforts to increase profits from an economic point of view. This is in line with the objectives of the sustainable manufacturing concept [8].

In the application of lean manufacturing, Value Stream Mapping (VSM) is used to analyze waste that occurs during the production process so that the industry can meet customer requirements to remain competitive with other companies [6].

Sustainable manufacturing has become a new paradigm involving the use of sustainable processes and systems to produce more sustainable products, is currently becoming increasing important. Many studies have been conducted related to research on sustainability and resulted in a system for measuring the performance of sustainable maintenance in several industries. For example, a study has been conducted to analyze the mapping of lean sustainable maintenance in the company to enhance the sustainable maintenance performance by using lean competitive manufacturing strategy [9].

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Research related to the evaluation of sustainability performance using SVSM is increasingly being used. Sustainable Value Stream Mapping (SVSM) extends traditional value stream mapping by combining three aspects, namely environmental aspects for evaluating environmental sustainability and social aspects for evaluating community sustainability at the production line level. The addition of this aspect allows all three aspects of sustainability to be evaluated for the production line, and for potential improvements to sustainability performance to be identified [10]. In some research, improvements are made to the design of analytical tools based on lean and sustainable manufacturing which are validated by conducting case study at some companies. The analytical tool is able to identify potential problems in the economic, environmental, and social aspects which are the pillars of sustainable manufacturing. If this problem can be reduced, the level of sustainability will increase [11].

Sustainability awareness is a step used to find out how well the company understands about sustainability. The tools used to measure sustainable awareness to find out the drivers, barriers and benefits of sustainability in the company. Sustainability drivers are factors that support companies to implement the sustainable concept. Barriers of sustainability are factors that hinder companies from implementing the sustainable concept. Benefits of sustainability are used to find out what benefits and benefits will be obtained by the company in implementing the concept of sustainable manufacturing [4]. Next, a sustainability index should be designed in such a way that it becomes applicable to all industry. The index should be chosen carefully so that it truly reflects the sustainability of a manufacturing organization [12].

The strategy in achieving sustainability is to implement the 6Rs, namely reduce, reuse, recycle, redesign, and remanufacturing. Reduce is an action to minimize the use of materials and waste produced to preserve the environment. Reuse is the process of reusing waste raw material, this strategy is more often rated as the most efficient and most effective primary strategy on environmental and economic impacts. Recycle is the use of certain processes to reuse materials that were originally waste materials that cannot be used for the same purpose or other purposes [13]. The 3R strategy developed into 6R with the addition of recover, redesign and remanufacture. The recovery strategy is the collection of waste products from production that will be repaired into usable products. The redesign strategy is a simplification at the final stage of the production process that considers the impact on the environment and an increase in production performance by carrying out a remanufacturing strategy [14].

The automotive industry is one of the largest business sectors in Indonesia with an investment of Rp 99.16 trillion with a total production capacity of 2.35 million units per year and absorbs 38.39 thousand direct workers in 2020. The automotive sector also has an impact for businesses in the chain.

PT. GSB is one of the largest automotive battery manufacturers in Indonesia. The company produces more than 16 million battery products annually. For the production process, the main raw material is tin, which is a non-renewable natural resource, so its availability will decrease over time. Pollution and waste generated from the production process continues to increase. Based on data on the amount of B3 waste that is currently managed, the company produces 4610.5 tons of B3 waste annually.

Currently the company has started to implement the concept of sustainability, this can be seen from the existence of a sustainability report that is owned by the parent company. Based on the sustainability report held in 2020, one of the actions the company wants to take is to make environmentally friendly products, one of which is to reduce the use of materials during the production process. The company has also received certifications in the form of ISO 14001, SMK3 and ISO 45001.

The problem experienced by the company is that the production department cannot maintain its production achievements. This happens due to waste in the form of waste transportation, defects, waiting and inappropriate processing contained in the activities of the production process. This waste causes the production process to be inefficient. This waste also causes an increase in the waste generated during the production process. Currently there is also a risk of work accidents that occur during the production process.

The purpose of this research is to analyze the results of mapping lean sustainable manufacturing in the motor vehicle battery company.and provide a proposed strategy in order to enhance the performance of sustainable manufacturing

2 RESEARCH METHODOLOGY

The research methodology consists of four main sections: creating SVSM, measuring the Sustainability Index (SI) , waste analysis using Ishikawa Diagram and proposed improvements. The SVSM will monitor the variability in terms of processing time and resource use and assess sustainable manufacturing performance on economic, environmental, and social aspects. The calculation of the SI begins with the sustainability index indicator, followed by determining the weight of the pillars using the pairwise comparison method. The next step is the SI calculation. The calculation of the SI followed the formula developed by Garbie [4] and also by Sari et al. [3].

The data collected includes primary data and secondary data. Primary data was obtained by using questionnaires and direct observation of the company, while secondary data was obtained through historical data of the company. At the initial stage of data processing, measurement of sustainability awareness and determination of sustainability drivers, barriers and benefits was carried out using a questionnaire. The next step is to calculate the standard time. The next stage is the creation of Current Sus-VSM with Traffic Light to map the company's sustainability indicators. Identification of the causes of waste is done by using the Ishikawa diagram to find the root of the problem. Next is the calculation of the Sustainability Index based on the target and actual data owned by the company. Based on the root cause of the waste and the gap between the performance indicators of the sustainability target and the actual, proposed improvements are given to improve the company's performance.

3 RESULTS AND DISCUSSIONS

3.1 Motor Vehicle Battery Company

PT. GSB is a manufacturing company that produces motorized vehicle batteries located in Karawang, West Java. Product sales are carried out for 3 types of markets, namely Original Equipment

Figure 1: MCB MF product.

(OE), Replacement Market (RM), and Export Market. The products produced by the company have many variants, but in general the products produced can be grouped into 2, namely Automotive Battery (AMB) and Motorcycle Battery (MCB). AMB is a type of battery used for 4-wheeled vehicles or cars while MCB batteries are batteries used for 2-wheeled vehicles or motorcycles. This research is focused on MCB MF products because they have the highest demand. MCB MF is a battery for 2-wheeled vehicles that does not need to be recharged regularly (Maintenance Free). The following is a picture of the MCB MF battery product. The main raw material for making batteries is tin. For MCB MF tin, the mixture used is PbCa, which is a mixture of tin (Pb) and Calcium (Ca).

The process of making automotive battery at PT. GSB starts from the casting process, which is the smelting of tin into a grid. Furthermore, the grid will be given a chemical solution in the form of a paste in the pasting process and becomes a plate. Then the plate will be processed in the formation section. After that the plate will be cut in the cutting area using a cutting machine and go through a brushing process. After that the plate will be assembled with other battery components. The last stage in making the battery is the process of charging or charging the battery which is then followed by the finishing process.

Currently, the company has implemented 2 of the 6 R strategies on the concept of sustainability, namely recycle and reuse. In the casting process, items that have defects will be reused for the casting process so that the waste generated will be reduced. The recycle policy is carried out for reject products or those that do not meet the company's quality standards in the finishing process, will be recycled and the results will be reused as raw materials for the production process.

The company already has a policy regarding the processing of B3 waste generated from the production process. The company currently also has a Waste Water Treatment facility that is used to recycle water from the production process that has been contaminated with chemicals so that it can be reused. The company has also implemented 5S, so the overall work environment at the company is quite good.

The biggest sustainability drivers currently owned by the company are building a corporate image, regulations, social responsibility and the need to increase efficiency and save costs. The biggest sustainability barriers factor owned by the company is the idea that implementing the concept of sustainability requires additional costs. The biggest sustainability benefits that companies get when implementing the concept of sustainability are improving the company's image, improving the company's brand image and increasing customer trust.

3.2 Sustainability VSM at Motor Vehicle Battery Company

Making Sustainable Value Stream Mapping (SVSM) involves sustainability indicators in general Value Stream Mapping, namely Economic, Social and Environmental indicators. SVSM uses a traffic light system with the following information: Red (0 – 65%) – Critical, Yellow (66 – 89%) – Moderate and Green (90 – 100%) – Excellent.

SVSM is also equipped with a kaizen burst that provides information about problems in the work areas of the production process. The Kaizen burst contained in the SVSM is also divided into 3 colors, namely pink, yellow and green. Pink color indicates economic problems, yellow color indicates social problems and green color indicates environmental problems. Based on the mapping results, the Manufacturing Lead Time (MLT) value is 2922.53 minutes, with a Percent Cycle Efficiency (PCE) value of 96.15%.

The results of the analysis show that the waste contained in the production process is waste waiting, transportation and inappropriate processing. Based on the Ishikawa diagram for each waste, it can be seen the cause of each waste. For example, in the pasting section, a defect occurs in the unformed plate which causes a hole in the unformed plate. This defect occurs due to an error when setting the belt pasting machine which makes the plate too thin so that it is easily perforated when processed by the machine. Error setting on the pasting belt can also cause defects in the form of plates that are too thick. This error occurs because there is no standard setting for the belt pasting machine and there are several types of plates that have different thicknesses.

The implementation of the Reuse and Recycle strategy has been applied to the production process of making motor vehicle batteries. Reuse strategy is applied to the Casting, Forming and Charging processes. In casting, the defective product resulting from the casting process is put back into the machine so that it can be reused. For the forming and charging processes, defective products are checked first, if they can still be used, they will proceed to the cutting process. The charging process is carried out by doing a recharge process for defective batteries that have been stored for too long. Recycle strategy is applied to the pasting, forming, cutting, assembly, charging and finishing processes. Scraps from the production process and defective products are collected and then sent to a 3rd party for recycling.

3.3 Calculation of Sustainability Index

The Sustainability Index is a measure of the extent to which a company has succeeded in achieving sustainability.

The calculation of the sustainability index is carried out by determining the sustainability index indicator, calculation of the weights using pairwise comparison method and finally calculation of the sustainability index.

3.4 Determining Sustainability Index Indicator

After observing and interviewing several selected company staff, several sustainability index indicators can be determined based on economic, environmental, and social pillars that will be used to measure the sustainability index value so that the level of sustainable manufacturing for the company can be determined. The

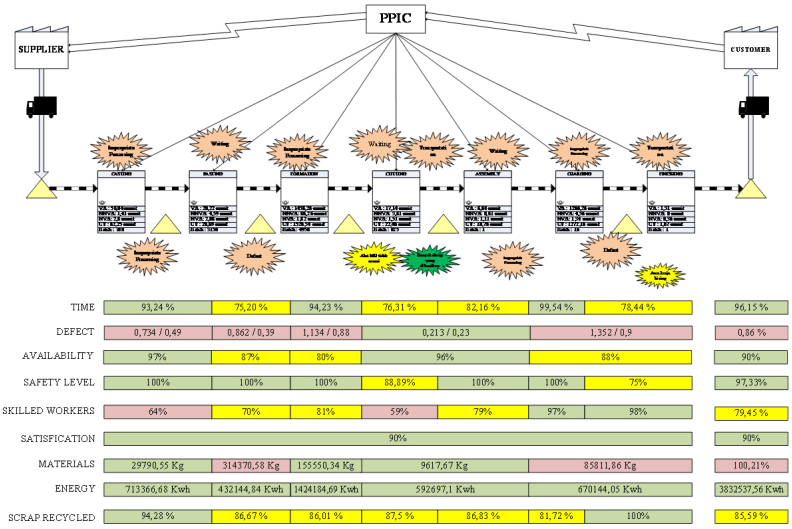

Figure 2: Current state sustainable value stream mapping.

Table 1: Calculation of sustainability index (SI)

Indicator		Performance measure	Existing	Target	Value of change	Percentage	Yij	Iij	Iij^Yij	S/Sdei		Eigen Vector	Sustainability Index	
Economy	Time	%	96,15	100	3,85	4,00%	0,59	1,040	1,023	1,414	141,36%	0,49	1,443	144,3%
	Defect	%	0,86	0,58	-0,28	-32,56%	-0,55	0,674	1,243					
	Availability	%	90,00	100	10,00	11,11%	1,00	1,111	1,111					
Social	Skill Workers	%	79,45	100	20,55	25,87%	1,31	1,259	1,353	1,52	152,03%	0,44		
	Safety Level	%	97,33	100	2,67	2,74%	0,43	1,027	1,012					
	Satisfaction	%	90,00	100	10,00	11,11%	1,00	1,111	1,111					
Environment	Energy	Kwh	3832537,56	4200616,72	368079,16	9,60%	--	--	--	1,199	119,93%	0,08		
	Scrap Recycled	%	85,59	100	14,41	16,84%	1,16	1,168	1,198					
	Materials	Ton	100,21	100	-0,21	-0,21%	-0,68	0,998	1,001					

information on the selected indicators for the measurement of the sustainable index at PT GSB can be seen at table 1.

The selection of indicators is determined based on the sustainability report that has been prepared by the GSB parent company. The following are the sustainability indicators used. The indicators for the economic pillars are: time, defect and availability, the social pillars are: skilled workers, safety level and satisfaction and the environmental pillars are: energy, recycled scrap and materials.

3.5 Calculation of the pillars' weights

The next step is to calculate the weights using a pairwise comparison approach for the three sustainability aspects. The weight calculation is carried out in order to determine the level of importance between aspects and which aspects affect the most according to the company's circumstances. The first step in this weighting is to conduct interviews with experts so that the level of importance between aspects is known. The results of the calculation of the weight of the criteria for the three aspects can be seen in table 1 (vector eigen column).

3.6 Calculation of Sustainability Index

After the target and existing values for each indicator were obtained, then the sustainability index was calculated for each indicator that had been selected according to the company's conditions. The following are the results of the calculation of the sustainability index at PT GSB which are shown in the table 1.

Table 1 shows that the economic pillar indicators that need attention are the defect indicators (1,243), for the social pillars are skill workers (1,353) and the environmental pillars are scrap recycled (1,198. The weight values of the economic pillars, social pillars and environmental pillars are based on pairwise comparison calculations. are 0.49, 0.44 and 0.08 which indicate the company's priority towards the sustainability.

Based on the calculation of the sustainability index, the results obtained for the economic aspect is 141.36%, the social aspect is 152.03%, and the environmental aspect is 119.93%. The overall SI indicator is 144.3%. The larger the SI value, the more attention it needs to make improvements.

The SI value of the company cannot be compared with the SI value of other similar companies. The results of the calculation of

the SI value are the basis for the company's consideration to determine the direction of improvement that the company must make to become a more sustainable company. From the SI calculation result for the motor vehicle battery company show that the GSB company needs to make improvements for being a sustainable company.

3.7 Proposed Improvements

The proposed improvements as a strategy to improve the company's sustainability performance are as follows:

1. Use of a digital counter to simplify the process of calculating the number of grids in the casting area; Incorporation of inspection processes; Performing grid lifter set-up while the previous process was in progress as well as Merging several processes (e.g. merging the inspection process, merging the process of installing connectors and cables and setting up a charging machine; merging the process of removing cables and connectors in the charging area) to reduce waste due to inappropriate processing.

2. More focused application of 5S and replacement of material handling tools to reduce waste due to transportation.

3. Increasing the number of maintenance staff and providing safety stock of spare parts to speed up the machine repair process and reduce waste due to waiting.

4. Utilization of the Poka-Yoke concept by using iron plate tools as well as making SOPs for the activities of setting up the belt pasting machine.

The use of iron plate tools is proposed to prevent operator errors when setting the machine to reduce waste due to defects. The defect in the form of a plate that has holes is caused by an error when setting the belt pasting machine. To prevent the operator from making mistakes when setting up, the suggestion that can be given is to use a tool in the form of an iron plate that has the same thickness as the plate you want to produce. This iron plate can be adjusted in thickness based on the type of plate you want to produce. This iron plate can be used to check whether the height setting on the belt pasting machine is in accordance with the thickness of the plate you want to produce or not. In addition, the proposed SOP is also used to assist operators in setting the belt pasting machine. This SOP is used so that each operator can properly setup the machine when there is a change of work operator or shift change.

4 CONCLUSIONS

SVSM for the manufacture of automotive battery products at PT GSB requires MLT of 2922.53 minutes, with a PCE value of 96.15% with inappropriate processing waste, waiting waste, defect waste and transportation waste. There is inappropriate processing waste in the casting, pasting, formation, assembly and charging areas. Waste waiting is found in the pasting, cutting and assembly areas. Waste defects is found in the pasting and charging areas, while transportation waste is found in the cutting and finishing areas.

The calculation of the Sustainability Index (SI) and obtained a value of 144.3% which indicates the need for improvement to become a sustainable company. Improvements in the form of the proposed lean manufacturing strategy are expected can enhance the company's performance so that it excels in the competition. The company is also expected to continue the implementation of the Reuse and Recycle strategy that has been carried out so far and add the implementation of the reduce strategy to the use of tin raw materials in the pasting and charging processes to enhance the sustainability of the company.

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REFERENCES

[1] M.A. Gbededo, K. Liyanage, A. Garza-Reyes. Towards a life cycle sustainability analysis: A systematic review of approaches to sustainable manufacturing, Journal of Cleaner Production, 184, 1002-1015. 2018.

[2] A. Moldavska, T. Welo. A Holistic approach to corporate sustainability assessment: Incorporating sustainable development goals into sustainable manufacturing performance evaluation, Journal of Manufacturing Systems, 50, 53-68. 2019.

[3] E. Sari, I.A. Marie, E. Erika, A.G. Chofreh, F.A. Goni, J.J. Klemeš and M. Zheinalnezhad, Lean sustainable competitive manufacturing strategy asessment: A case study in the Indonesian Car Manufacturing Company, Chemical Engineering Transactions, 88, 859-864. 2021.

[4] I. Garbie, Sustainability in Manufacturing Enterprises: Concepts, Analyses and Assessments for Industry 4.0. January. 2016.

[5] P. Teixeira, J.C. Sá, F.J.G. Silva, L.P. Ferreira, G. Santos, P. Fontoura. Connecting lean and green with sustainability towards conceptual model, Journal of Cleaner Production, 322. 2021.

[6] N. V. K. Jasti, & A. Sharma. Lean manufacturing implementation using value stream mapping as a tool. *International Journal of Lean Six Sigma*, 2014.

[7] L.J. Krajewski, M.K. Malhotra, L.P. Ritzman. Operation Management: Process and Supply Chains, 12th edition, Pearson, London, UK. 2019.

[8] A. Ishak, R. Ginting, V. Chandra. The application of lean manufacturing to minimise waste in Crude Palm Oil (CPO) production process at PT. XYZ, IOP Conference Series: Materials Science and Engineering, 505(1), 012143. 2019.

[9] I.A. Marie, E. Sari and C.A. Lika, Enhancing Sustainable Maintenance Performance Using Lean Competitive Manufacturing Strategy: A Case Study in Steel Company, *Solid State Technology* Volume: 63 Issue: 6, 2020.

[10] W. Faulkner and F. Badurdeen, Sustainable value stream mapping (sus-VSM): methodology to visualize and assess manufacturing sustainability performance, *Journal of Cleaner Production*, 2014.

[11] S. Hartini, U.M. Ciptomulyono, S. Anityasari and D. Pudjotomo. Sustainable-value stream mapping to evaluate sustainability performance: case study in an Indonesian furniture company, *Creative Commons Attribution License 4.0*, 2018.

[12] H. H. Latif, B. Gopalakrishnan, A. Nimbarte, and K. Currie, Sustainability index development for manufacturing industry, *Sustain. Energy Technol. Assessments*, vol. 24, pp. 82–95, 2017

[13] H. A. Kishawy, H. Hegab, and E. Saad, "Design for sustainable manufacturing: Approach, implementation, and assessment," *Sustain.*, vol. 10, no. 10, pp. 1–15, 2018, doi: 10.3390/su10103604.

[14] A. Ioannidis, K. J. Chalvatzis, L. C. Leonidou, and Z. Feng, "Applying the reduce, reuse, and recycle principle in the hospitality sector: Its antecedents and performance implications," *Bus. Strateg. Environ.*, vol. 30, no. 7, pp. 3394–3410, 2021, doi: 10.1002/bse.2809.

A Review on The Application of Machine Learning To Predict The Battery State That Enables A Smart, Low-Cost, Self-Sufficient Drying And Storage System for Agricultural Purposes

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ABSTRACT

This study reviews studies on a more viable battery for the energy storage system, the development of battery technology is towards a high capacity, low cost, and long battery lifespan. An accurate prediction of battery state, such as the state of charge, is important to help control the battery charging and discharging and extend the battery lifespan. Several reviews have provided an insightful summary regarding the development of methods to predict battery state for energy storage. This study provides a review that explores the application of machine learning to predict the battery state, including state of charge, state of health, and remaining useful life. Recent studies within this review shown that 64.7% researcher used Neural Network to do prediction with few studies do method combination to further overcome battery dynamic condition in real world application with less computational time and cost to enable integration with IoT technology. Furthermore, the opportunity to implement the energy storage system techniques to enable a smart, low-cost, self-sufficient implementation of the smart solar dryer for agricultural purposes is also elaborated

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CCS CONCEPTS

• **Computing methodologies**; • **Machine learning**; • **Machine learning algorithms**;

KEYWORDS

Battery state prediction, Literature review, Machine learning, Smart solar dryer

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1 INTRODUCTION

In food supply chains, inadequate food handling and storage, poor infrastructure, and limited food preservation capacity lead to food losses, especially for highly perishable foods [1]. Furthermore, in developed countries, post-harvest food losses are most likely to occur at the consumption stages. In less developed countries, most losses mainly occur in post-harvest handling and processing, which is at the early stage of the supply chain [2]. Drying is one of the techniques currently used in food processing. It is the removal of moisture that can prevent mold and bacteria from ruining the food. Drying has been used to preserve various products since many years ago. Solar drying is one of the commonly used methods for food drying. The advantages of drying include sustaining the product flavor, nutrients, and quality, enhancing appearance, extending

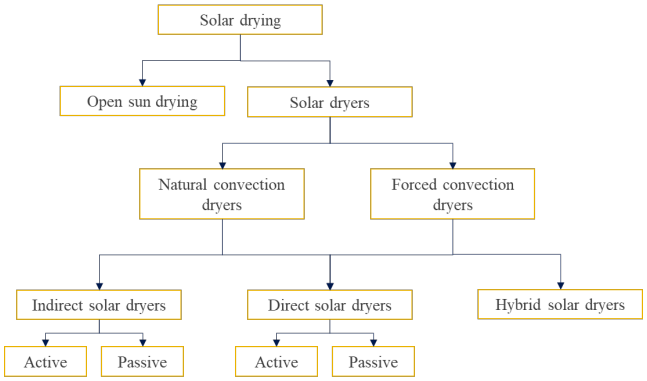

Figure 1: Classification of solar dryers [6]

shelf life for consumer utilization, reducing packaging and shipping capacity [3].

Various types of solar dryers have been developed to reduce post-harvest losses. Figure 1 shows the illustration of the classification of solar dryers. In the rural areas of tropical countries, due to its simplicity and affordability, perhaps the most preferred method is the open-air sun drying method. However, this drying process is heavily affected by the environment's dynamic, such as rain, wind, cloud, dust, and pests [4]. The suboptimal conditions lead into a low-quality product and a loss of income for the farmers. Another approach for drying known as solar dryers which shown to be faster, more efficient, more hygienic, and resulting in lower crop losses compared to the traditional open-air sun drying approach [5]. The solar dryers in figure 1 are classified as passive, active, and hybrid based on the method of air movement (natural or forced convection) and the mode of heat transfer (direct, indirect, or hybrid) [6]. One example of a greenhouse dryer with a parabolic shape is a solar dryer dome (SDD). SDD can be configured as a passive solar dryer or an active solar dryer. An active SDD has a ventilation system to circulate air inside the drying chamber using a blower that runs with minimum electricity harnessed from a photovoltaic (PV) module or grid. Using renewable energy sources such as photovoltaic is viable for remotes and rural areas. However, the current model of SDD with PV as energy sources is only sufficient during the day with enough frequency of sunlight [7]. Thus, there is a need to have an energy storage system that accompanies the power generation by PV for SDD to have a 24/7 operations time.

One of the barriers to PV adoption with ESS is the battery capacity and high up-front price [8]. The battery is one of the main components in ESS. Several types of batteries commonly used are lead-acid, nickel-metal hydride, nickel-cadmium, and lithium-ion batteries [9]. To have a more viable battery for ESS, the development of battery technology is towards a high capacity, low cost, and long battery lifespan. An accurate prediction of battery state, such as the state of charge, is important to help control the battery charging and discharging and extend the battery lifespan [10]. Several reviews have provided an insightful summary regarding the development of methods to predict battery state for energy storage [11],[12],[13]. Many reviews mentioned that machine learning is emerged as one of the promising techniques to determine the condition of charge (SOC), state of health (SOH), and remaining useful life (RUL)[11]. Despite the success of applying machine learning technique on predicting battery state, these techniques is mainly reported on the application of lithium-ion battery and the study case of electric vehicles.

This study provides a review that explores the application of machine learning to predict the battery state, including state of charge, state of health, and remaining useful life. Furthermore, the opportunity to implement the ESS technique to enable an imaginative, low-cost, self-sufficient on implementation of the smart solar dryer for agricultural purposes is also elaborated.

The remainder of this paper is organized as follows. Next section presents the review on the smart solar dryer. Then it follows by section with summarizes studies on machine learning applications to predict battery SOC, SOH, and RUL. Then the following section provides review result and analysis. Finally, The last section discuss conclusions and proposes future research directions.

2 GREEN HOUSE SOLAR DRYER

A solar dryer dome, also known as a solar greenhouse solar dryer, consists of an enclosed structure of frames covered with suitable cladding material [14]. Inside the greenhouse, trays are placed to distribute the products that need to be dried. The design commonly has a vent to allow air movement from inside the dryer to the atmosphere. This part reviews some features of the solar dryer dome, including design, economic, social, and environmental aspects. In addition, a discussion towards a smart solar dryer dome is provided.

2.1 Design Aspects

The design aspect here refers to covering materials and geometrical parameters such as the shape of the greenhouse solar dryers and the built orientation. In their review, Srinivasan & Mutukumar [14] mention that silica glass provides higher greenhouse temperature among many studies covering PVC, polyolefin, and polyethylene. However, low-density polyethylene is preferable due to its higher solar radiation transmissivity and low dust and dirt accumulation. There are many shape options for greenhouse solar dryers: even, uneven, vinery, modified arch, quonset, elliptical, golith, and gable [15]. In addition, the combination of orientations options commonly chosen are east-west and north-south. Some studies reported that the east-west direction has been reported to have maximum solar incident radiation [16], less energy for heating [17], and preferred for crop cultivation and drying process [18]. However, the preference regarding the shapes of the greenhouse dryers varies from one study to the others.

2.2 Economical – Social – Environmental Aspects

Evaluating social, economic, and environmental aspects of greenhouse solar dryers is a complex process due to multiple criteria and perspectives that can be considered. Greenhouse solar dryer is regarded as a high capital approach. Thus, it is necessary to determine the economic viability of the investment that need to be made [19]. The indicator of economic viability can be associated with the annualized costs, life cycle savings, and payback period [20].

Despite the burden of the financial aspect of adapting a greenhouse solar dryer, the social and environmental factors provide different perspectives that tend to support the long-term plan's adaptation. Significantly, the greenhouse solar dryer is powered by renewable energy sources.

It is commonly powered using fossil fuel electricity to have a stable energy supply for greenhouse drying [21]. Nevertheless, this type of energy, its current viability, has a negative impact on the environment. With the massive social movement led by governments and industries, many attempts have been addressed to switch from fossil fuel-based to renewable energy such as solar power. Governments worldwide have shown a positive movement by legislating incentives and tax credits for the use of renewable energy [22]. In addition, several environmental parameters are used to determine the use of renewable energies in the industry, such as carbon credit and CO2 mitigation.

2.3 Smart Solar Dryer

The development of smart solar dryer especially for greenhouse solar dryers, is eventually possible with much attention and support were given by the industry, government, and academia on Industry 4.0. Industrial Internet of Things (IIoT) and Machine Learning (ML) are two examples of such revolutionary Industry 4.0 technologies that revolutionized many industries. IIoT and ML have been successfully implemented in agricultural sectors for crop management, precision agriculture, crop quality and quantity improvement, and crop monitoring. Despite its various applications in agricultural areas, the implementation of IIoT and ML techniques to improve the current technologies of the solar dryer is considered seldom.

IIoT and ML have considerable roles to become the key that unlocks the potential of so-called smart solar dryers or smart greenhouse solar dryers. Application IIoT and ML in the smart greenhouse solar dryers can take parts in two main subsystems. IIoT sensors can monitor the environmental/weather and technical/yield data from the system. The collected data can be used for machine learning methods to predict electricity generation and demand on consumer sites in short (minutes till hour) and medium-term (days). Those methods shall increase system efficiency and predictive maintenance options for essential components. Another critical component for smart greenhouse solar dryer is energy storage system technology. Machine learning technology has been reported to be useful for estimating the level of available electrical energy. The application predicts the state of charge, state of health, and remaining useful life.

3 MACHINE LEARNING APPLICATION TO PREDICT BATTERY SOC, SOH, AND RUL

Due to the increasing demand for batteries in the market, battery knowledge needs to be improved to understand how to design a battery with the best behavior or optimize the battery. Each of past literature has a different focus/interest of battery behavior prediction, such as the type of battery (e.g., Li-Ion, lead-acid, etc.), a new novelty or combination algorithms for high accuracy model generation, or even to predict at a different level of battery (battery module and battery cell). Past research with model-based methods, it requires extensive knowledge of battery chemistry to construct with statistical approach and mathematical optimization for good accuracy. However, these models can only be applied to those specific type of battery and operating condition because its result can be affected by unprecedented internal chemical reaction, environmental interference and noise behavior. All the problems can be solved with machine learning – a promising approach to computer programs that learn from data. Table 1 summarized the approaches taken by a range of authors in the past few years. First, the table summarizes the most common machine learning techniques for predictive analysis of batteries. Finally, it outlines the algorithm to predict SOC, SOH and RUL.

The neural network is the most widely used approach for predicting SOC, SOH and RUL. The method can achieve high accuracy by using a multi-layer model structure. It is depicted in table 1 that 22 out of 34 approaches are preferred using neural networks. By far, a neural network is used frequently, especially in predicting SOC that needs a large training dataset. Model-based such as Kalman Filter and data-driven techniques such as regression are rarely used because they are sensitive to noise and having a lower accuracy level than neural networks. Prediction with SVM is proven to be least used due to nonlinear battery dynamic that hard to be characterized except in certain controlled environment.

Data-driven prediction methods often extract observable time series data from the battery and then employ machine learning techniques to construct a learning model. Recent studies (see table 2) shows that most SOC prediction uses basic battery parameter such as voltage, current, temperature as their main input. SOC prediction result can be fluctuant especially when used with untrained ambient temperature data (especially below 00C) and change of battery dynamics due to degradation along its lifetime [36], [37], [42], [43], [58]. Few studies use combined method to further overcome each technique weakness such as CNN with GRU[37] , RNN with LSTM[23], NN with EKF [36], Dual Kalman Filter [54].

SOH prediction proved to be more challenging with a lot of parameters being used to do prediction because it can be affected by many factors such as battery degradation, charge and discharge rate, storage temperature, usage, and data noise. Meanwhile RUL prediction using less parameter with voltage, current (charging and discharging), and capacity to achieve accuracy.

For both SOH and RUL prediction, researcher combined common measurable parameter of voltage, current and temperature with experimental method factors of resistance, capacity and depth of discharge to improve prediction result. Same with SOC prediction, using combined method such as RNN LSTM with empirical mode decomposition [48], SVM with regression [32], LSTM with Gaussian [59], Regression with Gaussian [28], SVM with Kalman Filter [31], LSTM with RNN [49], GRU with CNN [46], [50] to achieve good prediction result under varying temperature and working environment.

Time-series data calculated through various machine learning methods with more data will produce better accuracy. 27 out of 34 papers use a combined method, either filtering or additional method for prediction to achieve great results over 98% accuracy with fewer data. Filtering reduces noise in prediction so learning data can be more accurate to construct a better learning model. Hosain Lipu et al [10] state few challenges on data driven methods is overfitting data with undetected noises, data source from controlled

Table 1: Summary of Recent Studies for Battery State Prediction

Method	Prediction		
	SOC	SOH	RUL
Regression	[23], [24]	[25]–[30]	[28], [29], [31]–[33]
Random forest / Decision Tree	-	[28], [34], [35]	-
Neural Network	[36]–[43]	[34], [44]–[49]	[42], [45], [47]–[51]
SVM	[52]	[53]	-
Gaussian/Bayesian	[24]	[28], [30]	-
Kalman Filter	[36], [54]–[57]	[56]	[31], [57]

Table 2: Summary of Input and Output Parameters for Battery State Prediction

Input Parameters	SOC	SOH	RUL
Voltage	[23],[24],[25], [36],[37],[38],[40] ,[41],[42],[43],[44], [54],[55]	[27], [29], [30], [44]–[49], [60]	[32], [33], [47], [57]
Current	[23],[24],[25], [36],[37],[38],[39],[40] ,[41],[42],[43],[[44], [54], [55]	[27], [29], [30], [44], [46]–[49], [60]	[31]–[33], [47], [57]
Temperature	[23]–[25], [36]–[43]	[29], [46], [60]	[31]
Resistance (Ohm)	[54], [55]	[26], [44], [46], [53], [56]	-
Capacity	-	[29], [30], [46], [48], [49], [53]	[32], [33], [48], [49], [51], [61]
Depth Of Discharge	-	[34]	-

environment, selection of structure with hyperparameter tuning, also long training time which not compatible to most embedded BMS hardware capability in battery. Even tough machine learning demands good quality and huge quantity of training data with long computational time and cost but in general it can produce good prediction result.

4 RESULTS AND ANALYSIS

This review provides an elaborated review on a pool of works related to utilizing machine learning to predict the battery state, such as SOC, SOH, and RUL. Furthermore, this review also describes the benefit of having a better prediction on battery SOC, SOH, and RUL can enable a smart, low-cost, self-sufficient drying and storage system for agricultural purposes in a case of a greenhouse solar dryer. This review indicates a need for implementing a better solar dryer technology that will drive to a more economical, social, and environmental viable product. Recent studies within this review shown that 64.7% researcher used Neural Network to do prediction with few studies do method combination to further overcome battery dynamic condition in real world application. As its application move toward online real-time with Internet of Things (IoT), researcher need to pay more attention for efficient prediction method with less computational time and cost while dealing with more data. Further review on the approaches to predict state of charge, state of health, and remaining useful life of battery shown that machine learning algorithms has become one of the favorable and effective approach given enough data.

5 CONCLUSION

Research in the battery field is expanding rapidly which attracted a lot of attention from researchers and scientists. This is due to the high development of technology that rely in the stored power. The review was conducted on the battery model prediction of SOC, SOH and RUL. Two important parts of the review are,

- Battery prediction algorithm methods: six of algorithm to predict SOC, SOH and RUL in the battery field has been reviewed. Neural network methods are highly favorable for battery predictions due to the capability to handle battery dynamic conditions compare to other methods such as regression, random forest/decision tree, SVM, gaussian/Bayesian, and Kalman filter.
- Prediction input parameter for developing the model: Most of the researches has considered only using fewer important input parameter like voltage, current, temperature and capacity. Parameter selection could lead into faster algorithm execution, reduce model complexity, increase model accuracy and reduce over-fitting.

Data-driven methods with accurate result are required to become optimization enablers in the future agriculture innovation (e.g., Smart Solar Dryer). Moreover, the model will be implemented in

the BMS to have a real-time monitoring prediction which generate high advantages into the user. However, there are various other methods and the methods improvement is still ongoing to improve the model accuracy. Further research to explore the other methods is required in this field.

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REFERENCES

[1] Food and Agriculture Organization FAO, "The State of Food Security and Nutrition in the World 2021," State Food Secur. Nutr. World 2021, Jul. 2021, doi: 10.4060/cb4474en.

[2] R. J. Hodges, J. C. Buzby, and B. Bennett, "Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use," J. Agric. Sci., vol. 149, no. S1, pp. 37–45, 2011, doi: 10.1017/S0021859610000936.

[3] A. Kamarulzaman, M. Hasanuzzaman, and N. A. Rahim, "Global advancement of solar drying technologies and its future prospects: A review," Sol. Energy, vol. 221, pp. 559–582, 2021, doi: 10.1016/j.solener.2021.04.056.

[4] H. El Hage, A. Herez, M. Ramadan, H. Bazzi, and M. Khaled, "An investigation on solar drying: A review with economic and environmental assessment," Energy, vol. 157, pp. 815–829, Aug. 2018, doi: 10.1016/j.energy.2018.05.197.

[5] V. Tomar, G. N. Tiwari, and B. Norton, "Solar dryers for tropical food preservation: Thermophysics of crops, systems and components," Sol. Energy, vol. 154, pp. 2–13, Sep. 2017, doi: 10.1016/j.solener.2017.05.066.

[6] P. Udomkun *et al.*, "Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach," J. Environ. Manage., vol. 268, p. 110730, Aug. 2020, doi: 10.1016/j.jenvman.2020.110730.

[7] J. C. Tu and C. Yang, "Key factors influencing consumers' purchase of electric vehicles," Sustain., vol. 11, no. 14, 2019, doi: 10.3390/su11143863.

[8] E. Karakaya and P. Sriwannawit, "Barriers to the adoption of photovoltaic systems: The state of the art," Renew. Sustain. Energy Rev., vol. 49, pp. 60–66, Sep. 2015, doi: 10.1016/j.rser.2015.04.058.

[9] W.-Y. Chang, "The State of Charge Estimating Methods for Battery: A Review," ISRN Appl. Math., vol. 2013, pp. 1–7, 2013, doi: 10.1155/2013/953792.

[10] M. S. Hossain Lipu *et al.*, "Data-driven state of charge estimation of lithium-ion batteries: Algorithms, implementation factors, limitations and future trends," J. Clean. Prod., vol. 277, p. 124110, Dec. 2020, doi: 10.1016/j.jclepro.2020.124110.

[11] M.-F. Ng, J. Zhao, Q. Yan, G. J. Conduit, and Z. W. Seh, "Predicting the state of charge and health of batteries using data-driven machine learning," Nat. Mach. Intell., vol. 2, no. 3, pp. 161–170, Mar. 2020, doi: 10.1038/s42256-020-0156-7.

[12] W. Zhou, Y. Zheng, Z. Pan, and Q. Lu, "Review on the battery model and SOC estimation method," Processes, vol. 9, no. 9, 2021, doi: 10.3390/pr9091685.

[13] S. Park *et al.*, "Review of state-of-the-art battery state estimation technologies for battery management systems of stationary energy storage systems," J. Power Electron., vol. 20, no. 6, pp. 1526–1540, Nov. 2020, doi: 10.1007/s43236-020-00122-7.

[14] G. Srinivasan and P. Muthukumar, "A review on solar greenhouse dryer: Design, thermal modelling, energy, economic and environmental aspects," Sol. Energy, vol. 229, pp. 3–21, Nov. 2021, doi: 10.1016/j.solener.2021.04.058.

[15] H. G. Mobtaker, Y. Ajabshirchi, S. F. Ranjbar, and M. Matloobi, "Simulation of thermal performance of solar greenhouse in north-west of Iran: An experimental validation," Renew. Energy, vol. 135, pp. 88–97, May 2019, doi: 10.1016/j.renene.2018.10.003.

[16] S. M. Dragićević, "Determining the optimum orientation of a greenhouse on the basis of the total solar radiation availability," Therm. Sci., vol. 15, no. 1, pp. 215–221, 2011, doi: 10.2298/TSCI100220057D.

[17] M. J. Gupta and P. Chandra, "Effect of greenhouse design parameters on conservation of energy for greenhouse environmental control," Energy, vol. 27, no. 8, pp. 777–794, Aug. 2002, doi: 10.1016/S0360-5442(02)00030-0.

[18] N. Choab, A. Allouhi, A. El Maakoul, T. Kousksou, S. Saadeddine, and A. Jamil, "Review on greenhouse microclimate and application: Design parameters, thermal modeling and simulation, climate controlling technologies," Solar Energy, vol. 191. pp. 109–137, Oct. 2019, doi: 10.1016/j.solener.2019.08.042.

[19] N. Bekkioui, "Performance comparison and economic analysis of three solar dryer designs for wood using a numerical simulation," Renew. Energy, vol. 164, pp. 815–823, Feb. 2021, doi: 10.1016/j.renene.2020.09.126.

[20] A. Sreekumar, P. E. Manikantan, and K. P. Vijayakumar, "Performance of indirect solar cabinet dryer," Energy Convers. Manag., vol. 49, no. 6, pp. 1388–1395, Jun. 2008, doi: 10.1016/j.enconman.2008.01.005.

[21] S. Vijayavenkataraman, S. Iniyan, and R. Goic, "A review of solar drying technologies," Renew. Sustain. Energy Rev., vol. 16, no. 5, pp. 2652–2670, Jun. 2012, doi: 10.1016/j.rser.2012.01.007.

[22] G. Pirasteh, R. Saidur, S. M. A. Rahman, and N. A. Rahim, "A review on development of solar drying applications," Renew. Sustain. Energy Rev., vol. 31, pp. 133–148, Mar. 2014, doi: 10.1016/j.rser.2013.11.052.

[23] J. Hong, Z. Wang, W. Chen, L. Y. Wang, and C. Qu, "Online joint-prediction of multi-forward-step battery SOC using LSTM neural networks and multiple linear regression for real-world electric vehicles," J. Energy Storage, vol. 30, pp. 1–21, 2020, doi: 10.1016/j.est.2020.101459.

[24] F. Xiao, C. Li, Y. Fan, G. Yang, and X. Tang, "State of charge estimation for lithium-ion battery based on Gaussian process regression with deep recurrent kernel," Int. J. Electr. Power Energy Syst., vol. 124, no. January 2020, p. 106369, 2021, doi: 10.1016/j.ijepes.2020.106369.

[25] X. Tan, D. Zhan, P. Lyu, J. Rao, and Y. Fan, "Online state-of-health estimation of lithium-ion battery based on dynamic parameter identification at multi timescale and support vector regression," J. Power Sources, vol. 484, no. October, p. 229233, 2021, doi: 10.1016/j.jpowsour.2020.229233.

[26] D. Yang, Y. Wang, R. Pan, R. Chen, and Z. Chen, "State-of-health estimation for the lithium-ion battery based on support vector regression," Appl. Energy, vol. 227, no. March, pp. 273–283, 2018, doi: 10.1016/j.apenergy.2017.08.096.

[27] Y. Li *et al.*, "Random forest regression for online capacity estimation of lithium-ion batteries," Appl. Energy, vol. 232, no. September, pp. 197–210, 2018, doi: 10.1016/j.apenergy.2018.09.182.

[28] X. Li, Z. Wang, and J. Yan, "Prognostic health condition for lithium battery using the partial incremental capacity and Gaussian process regression," J. Power Sources, vol. 421, no. February, pp. 56–67, 2019, doi: 10.1016/j.jpowsour.2019.03.008.

[29] X. Li, C. Yuan, and Z. Wang, "Multi-time-scale framework for prognostic health condition of lithium battery using modified Gaussian process regression and nonlinear regression," J. Power Sources, vol. 467, no. February, p. 228358, 2020, doi: 10.1016/j.jpowsour.2020.228358.

[30] D. Yang, X. Zhang, R. Pan, Y. Wang, and Z. Chen, "A novel Gaussian process regression model for state-of-health estimation of lithium-ion battery using charging curve," J. Power Sources, vol. 384, no. March, pp. 387–395, 2018, doi: 10.1016/j.jpowsour.2018.03.015.

[31] Z. Xue, Y. Zhang, C. Cheng, and G. Ma, "Remaining useful life prediction of lithium-ion batteries with adaptive unscented kalman filter and optimized support vector regression," Neurocomputing, vol. 376, pp. 95–102, 2020, doi: 10.1016/j.neucom.2019.09.074.

[32] S. Li, H. Fang, and B. Shi, "Remaining useful life estimation of Lithium-ion battery based on interacting multiple model particle filter and support vector regression," Reliab. Eng. Syst. Saf., vol. 210, no. January, p. 107542, 2021, doi: 10.1016/j.ress.2021.107542.

[33] F. K. Wang and T. Mamo, "A hybrid model based on support vector regression and differential evolution for remaining useful lifetime prediction of lithium-ion batteries," J. Power Sources, vol. 401, pp. 49–54, Oct. 2018, doi: 10.1016/j.jpowsour.2018.08.073.

[34] N. Yang, Z. Song, H. Hofmann, and J. Sun, "Robust State of Health estimation of lithium-ion batteries using convolutional neural network and random forest," J. Energy Storage, vol. 48, 2022, doi: 10.1016/j.est.2021.103857.

[35] K. S. R. Mawonou, A. Eddahech, D. Dumur, D. Beauvois, and E. Godoy, "State-of-health estimators coupled to a random forest approach for lithium-ion battery aging factor ranking," J. Power Sources, vol. 484, pp. 1–25, 2021, doi: 10.1016/j.jpowsour.2020.229154.

[36] C. Chen, R. Xiong, R. Yang, W. Shen, and F. Sun, "State-of-charge estimation of lithium-ion battery using an improved neural network model and extended Kalman filter," J. Clean. Prod., vol. 234, no. 5, pp. 1153–1164, 2019, doi: 10.1016/j.jclepro.2019.06.273.

[37] Z. Huang, F. Yang, F. Xu, X. Song, and K. L. Tsui, "Convolutional Gated Recurrent Unit-Recurrent Neural Network for State-of-Charge Estimation of Lithium-Ion Batteries," IEEE Access, vol. 7, pp. 93139–93149, 2019, doi: 10.1109/ACCESS.2019.2928037.

[38] D. N. T. How, M. A. Hannan, M. S. H. Lipu, K. S. M. Sahari, P. J. Ker, and K. M. Muttaqi, "State-of-Charge Estimation of Li-Ion Battery in Electric Vehicles: A Deep Neural Network Approach," IEEE Trans. Ind. Appl., vol. 56, no. 5, pp. 5565–5574, 2020, doi: 10.1109/TIA.2020.3004294.

[39] B. Xia *et al.*, "State of charge estimation of lithium-ion batteries using optimized Levenberg-Marquardt wavelet neural network," Energy, vol. 153, pp. 694–705, 2018, doi: 10.1016/j.energy.2018.04.085.

[40] M. A. Hannan, M. S. H. Lipu, A. Hussain, M. H. Saad, and A. Ayob, "Neural network approach for estimating state of charge of lithium-ion battery using backtracking search algorithm," IEEE Access, vol. 6, pp. 10069–10079, 2018, doi: 10.1109/ACCESS.2018.2797976.

[41] G. C. S. Almeida, A. C. Z. de Souza, and P. F. Ribeiro, "A Neural Network Application for a Lithium-Ion Battery Pack State-of-Charge Estimator with Enhanced Accuracy," Proceedings, vol. 58, no. 1, p. 33, 2020, doi: 10.3390/wef-06915.

[42] X. Feng, J. Chen, Z. Zhang, S. Miao, and Q. Zhu, "State-of-charge estimation of lithium-ion battery based on clockwork recurrent neural network," Energy, vol.

236, p. 121360, 2021, doi: 10.1016/j.energy.2021.121360.

[43] F. Yang, W. Li, C. Li, and Q. Miao, "State-of-charge estimation of lithium-ion batteries based on gated recurrent neural network," Energy, vol. 175, pp. 66–75, 2019, doi: 10.1016/j.energy.2019.03.059.

[44] M. Talha, F. Asghar, and S. H. Kim, "A Neural Network-Based Robust Online SOC and SOH Estimation for Sealed Lead–Acid Batteries in Renewable Systems," Arab. J. Sci. Eng., vol. 44, no. 3, pp. 1869–1881, 2019, doi: 10.1007/s13369-018-3200-8.

[45] J. Qu, F. Liu, Y. Ma, and J. Fan, "A Neural-Network-Based Method for RUL Prediction and SOH Monitoring of Lithium-Ion Battery," IEEE Access, vol. 7, pp. 87178–87191, 2019, doi: 10.1109/ACCESS.2019.2925468.

[46] Y. Fan, F. Xiao, C. Li, G. Yang, and X. Tang, "A novel deep learning framework for state of health estimation of lithium-ion battery," J. Energy Storage, vol. 32, no. July, p. 101741, 2020, doi: 10.1016/j.est.2020.101741.

[47] S. Zhang, B. Zhai, X. Guo, K. Wang, N. Peng, and X. Zhang, "Synchronous estimation of state of health and remaining useful lifetime for lithium-ion battery using the incremental capacity and artificial neural networks," J. Energy Storage, vol. 26, no. July, p. 100951, 2019, doi: 10.1016/j.est.2019.100951.

[48] G. Cheng, X. Wang, and Y. He, "Remaining useful life and state of health prediction for lithium batteries based on empirical mode decomposition and a long and short memory neural network," Energy, vol. 232, p. 121022, 2021, doi: 10.1016/j.energy.2021.121022.

[49] P. Li *et al.*, "State-of-health estimation and remaining useful life prediction for the lithium-ion battery based on a variant long short term memory neural network," J. Power Sources, vol. 459, no. October 2019, p. 228069, 2020, doi: 10.1016/j.jpowsour.2020.228069.

[50] J. Chen, H. Jing, Y. Chang, and Q. Liu, "Gated recurrent unit based recurrent neural network for remaining useful life prediction of nonlinear deterioration process," Reliab. Eng. Syst. Saf., vol. 185, no. December 2018, pp. 372–382, 2019, doi: 10.1016/j.ress.2019.01.006.

[51] Y. Zhang, R. Xiong, H. He, and M. G. Pecht, "Long short-term memory recurrent neural network for remaining useful life prediction of lithium-ion batteries," IEEE Trans. Veh. Technol., vol. 67, no. 7, pp. 5695–5705, 2018, doi: 10.1109/TVT.2018.2805189.

[52] L. Zhang, K. Li, D. Du, C. Zhu, and M. Zheng, "A sparse least squares support vector machine used for SOC estimation of Li-ion Batteries," IFAC-PapersOnLine, vol. 52, no. 11, pp. 256–261, 2019, doi: 10.1016/j.ifacol.2019.09.150.

[53] J. Meng, L. Cai, G. Luo, D. I. Stroe, and R. Teodorescu, "Lithium-ion battery state of health estimation with short-term current pulse test and support vector machine," Microelectron. Reliab., vol. 88–90, pp. 1216–1220, 2018, doi: 10.1016/j.microrel.2018.07.025.

[54] Y. Xu *et al.*, "State of charge estimation for lithium-ion batteries based on adaptive dual Kalman filter," Appl. Math. Model., vol. 77, pp. 1255–1272, 2020, doi: 10.1016/j.apm.2019.09.011.

[55] Y. Zhao, J. Xu, X. Wang, and X. Mei, "The Adaptive Fading Extended Kalman Filter SOC Estimation Method for Lithium-ion Batteries," Energy Procedia, vol. 145, pp. 357–362, 2018, doi: 10.1016/j.egypro.2018.04.064.

[56] L. Fang, J. Li, and B. Peng, "Online estimation and error analysis of both SOC and SOH of lithium-ion battery based on DEKF method," Energy Procedia, vol. 158, pp. 3008–3013, 2019, doi: 10.1016/j.egypro.2019.01.974.

[57] Y. SONG, D. LIU, Y. HOU, J. YU, and Y. PENG, "Satellite lithium-ion battery remaining useful life estimation with an iterative updated RVM fused with the KF algorithm," Chinese J. Aeronaut., vol. 31, no. 1, pp. 31–40, 2018, doi: 10.1016/j.cja.2017.11.010.

[58] Q. Yan and Y. Wang, "Predicting for power battery SOC based on neural network," Chinese Control Conf. CCC, pp. 4140–4143, 2017, doi: 10.23919/ChiCC.2017.8028008.

[59] L. Mao, J. Xu, J. Chen, J. Zhao, Y. Wu, and F. Yao, "A LSTM-STW and GS-LM fusion method for lithium-ion battery Rul prediction based on EEMD," Energies, vol. 13, no. 9, 2020, doi: 10.3390/en13092380.

[60] J. Jia, J. Liang, Y. Shi, J. Wen, X. Pang, and J. Zeng, "SOH and RUL prediction of lithium-ion batteries based on Gaussian process regression with indirect health indicators," Energies, vol. 13, no. 2, p. 375, Jan. 2020, doi: 10.3390/en13020375.

[61] X. Pang, R. Huang, J. Wen, Y. Shi, J. Jia, and J. Zeng, "A lithium-ion battery rul prediction method considering the capacity regeneration phenomenon," Energies, vol. 12, no. 11, 2019, doi: 10.3390/en12122247.

Feasibility Evaluation Analysis of Mobile Tower Using Sensitivity Analysis and Monte Carlo Simulation

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ABSTRACT

In 2013, PT X received a request for the construction of 2,109 tower units which would later be rented out by PT Y. Thus, PT X started planning the tower construction in 2014. However, only 242 sites of the projected 856 towers were completed in the first quarter of 2014. This could lead to a potential withdrawal of the tower construction request by PT Y. As a consequence, PT X's management attempted to speed up the tower construction process by procuring mobile towers to serve as temporary replacement towers before conventional towers could be established. Therefore, feasibility study analysis was necessary for the purchase of the mobile towers. The data were collected by distributing questionnaires, conducting interviews, and gathering historical data of the company. Calculations were made based on these data for two alternative decision-making scenarios: without the purchase of mobile towers (alternative A) and with the purchase of mobile towers (alternative B). In addition, the calculations were done using several methods, namely net present value (NPV), internal rate of return (IRR), payback period (PBP), and profitability index (PI). From the two alternatives, alternative B was determined as the best alternative with an NPV of IDR 273 billion, an IRR of 13,81%, a PBP of 14 years and 10 months, and a PI of 1,14. Subsequently, a risk analysis was performed using sensitivity analysis for three variables, namely the possibility of increasing tower construction costs, decreasing revenue from tower rentals, and increasing tower operational costs. Among the three variables, the variable that most influenced NPV and IRR was a decrease in revenue from tower rentals with an NPV of IDR 32 billion and an IRR of 11.78%. Furthermore, Monte Carlo analysis was performed for three risk analyses simultaneously. From 10,000 trials, the probability of NPV < 0 was 1.06% and IRR < WACC was 1.03%, indicating that the chosen alternative (B) has a very small probability of failing. The study's findings led to the conclusion that alternative B would be the best option for PT X. The results of this study can also be a recommendation for other tower providers and further researchers to conduct further studies on the procurement of mobile towers.

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CCS CONCEPTS

• **General and reference**; • **Document types**; • **General literature.**;

KEYWORDS

Feasibility Study Analysis, Sensitivity Analysis, Monte Carlo Simulation, Mobile Tower, Telecommunication Tower

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1 INTRODUCTION

The development of the national telecommunications business in this era is considered very promising. In the mid-2014, the average performance of issuers in the telecommunication sector gave a positive performance. This is reinforced by the trend of increasing smartphone usage ratios, as evidenced by some issuers reporting an increase in net profit. This resulted from people who depend on mobile data to support their daily lives. However, telecommunication companies face challenges, namely government policies that reduce telecommunication costs. According to a circular stipulated by the Ministry of Communication and Information Technology, with a new calculation pattern, telecommunication costs for local cellular calls decreased, from around Rp250,00 per minute on 1 September 2016, to Rp204,00 per minute. To accommodate the decrease in telecommunication costs, telecommunication companies aims to raise their revenues by, among other choices, developing telecommunication infrastructures to expand their coverage. Network expansion to various regions in Indonesia will certainly support this business. As a result, telecommunication infrastructure companies that are qualified to support the expansion of the telecommunication business in Indonesia are also needed (cnnindonesia.com) [6].

PT X is a company engaged in leasing telecommunication towers to meet the needs of base transceiver station (BTS) placement for telecommunication operators throughout Indonesia. In 2013, PT X received a request for a permanent tower location, which would later be rented as many as 2,109 towers by PT Y. To fulfill this request, PT X made plans for the construction of 2,109 towers to be completed by the end of 2014. However, in its implementation, only 242 sites of the planned 856 sites had been realized by the first quarter (April) of 2014. If this persisted, the company was expected to only complete 1,240 towers by the end of 2014 as shown in Table 1.

Table 1: Estimated Completion of Tower Without Mobile Tower

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
North Sumatera	15	26	35	35	49	143	167	191	215	239	263	287	**287**
Central Sumatera	5	9	11	17	22	41	48	55	62	69	76	83	**83**
South Sumatra	20	31	39	40	43	54	63	72	81	90	99	108	**108**
Jabodetabek	14	25	26	27	33	71	83	95	107	119	131	143	**143**
West Jawa	24	31	31	32	37	41	48	55	62	69	76	83	**83**
Central Java	4	5	5	5	5	24	28	32	36	40	44	48	**48**
East Java	1	1	1	10	10	35	41	47	53	59	65	71	**71**
Balinusra	0	2	2	15	39	41	48	55	62	69	76	83	**83**
Kalimantan	0	16	17	22	30	78	91	104	117	130	143	156	**156**
Sulmapua	13	26	35	39	40	88	103	118	133	148	163	178	**178**
Total	**96**	**172**	**202**	**242**	**308**	**616**	**720**	**824**	**928**	**1.032**	**1.136**	**1.240**	**1.240**

Table 2: Estimated Completion of Tower with Purchasing Mobile Tower

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
North Sumatera	15	26	35	35	49	143	170	194	221	245	272	296	**296**
Central Sumatera	5	9	11	17	22	41	80	87	126	133	172	179	**179**
South Sumatra	20	31	39	40	43	54	95	104	145	154	195	204	**204**
Jabodetabek	14	25	26	27	33	71	114	126	169	181	224	236	**236**
West Jawa	24	31	31	32	37	41	72	79	110	117	148	155	**155**
Central Java	4	5	5	5	5	24	68	72	116	120	164	168	**168**
East Java	1	1	1	10	10	35	79	85	129	135	179	185	**185**
Balinusra	0	2	2	15	39	41	55	62	76	83	97	104	**104**
Kalimantan	0	16	17	22	30	78	129	142	193	206	257	270	**270**
Sulmapua	13	26	35	39	40	88	118	133	163	178	208	223	**223**
Total	**96**	**172**	**202**	**242**	**308**	**616**	**980**	**1.084**	**1.448**	**1.552**	**1.916**	**2.020**	**2.020**

Furthermore, this could lead to a potential withdrawal of the tower construction request by PT Y. To anticipate this, PT X's management attempted to accelerate the process of realizing the development plan by purchasing 260 mobile towers. According to calculations, with the purchase of mobile towers, the company was estimated to complete 2,020 towers by the end of 2014 as shown in Table 2.

Therefore, the following research questions were formulated to evaluate the procurement of mobile towers:

- Which alternative is feasible, without the purchase of mobile towers (alternative A) or with the purchase of mobile towers (alternative B)?
- How is the sensitivity analysis of the selected alternative?
- How is the Monte Carlo simulation calculated for the selected alternative?

2 THEORETICAL FRAMEWORK

2.1 About the Company

PT X is a company engaged in the telecommunication sector in Indonesia. Its main business is leasing telecommunication towers to meet the needs of base transceiver station (BTS) placement for telecommunication operators throughout Indonesia.

2.2 Logical Framework

2.2.1 Investment Plan. Based on Figure 1, an investment plan is the company's plan to spend on capital expenditures and operating

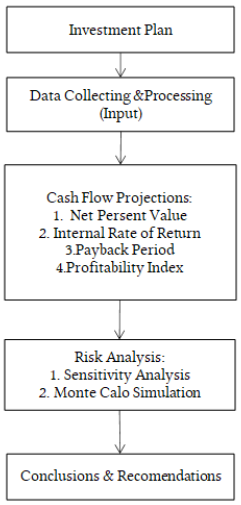

Figure 1: Logical framework

expenditures. From the investment plan, the amount of income in the future can be projected.

2.2.2 Data Collecting & Processing. The data collection was carried out by distributing questionnaires and conducting interviews with employees of PT X as well as gathering historical data of the company.

2.2.3 Cash Flow Projections. The cash flow projections were then carried out using Microsoft Excel, precisely to determine the net present value, internal rate of return, payback period, and profitability index. From these calculations, the best alternative was determined.

2.2.4 Risk Analysis. Risk analysis on the best alternative was performed using Microsoft Excel, namely the sensitivity analysis method and the Monte Carlo simulation to identify changes in the NPV & IRR values if one variable of capital expenditures and operating expenditures is changed.

2.2.5 Conclusions and Recommendations. Conclusions and recommendations for the company were drawn from the findings.

2.3 Investment Theory

Investment is a series of actions to invest a number of funds with the aim of getting added value in the form of profits (returns) in the future. Sharpe et al. (1995) [2] defined investment as follows, "Sacrificing assets owned now in order to get assets in the future which of course with a larger amount." Meanwhile, Jones (2004) [4] defined investment as a commitment to invest a number of funds in one or more assets over several periods in the future. The following are the fundamentals for performing the feasibility analysis and simulation in this study:

2.3.1 Net Present Value. Net present value (NPV) can be defined as the difference between the present value of cash inflows and the present value of cash outflows. The NPV of a project provides a measure of the net worth of an investment proposal in terms of current value for money. Because all cash flows are discounted back to the present, then the difference in the value of the current annual free cash flows is compared to investment expenditure. A project can be categorized as feasible if the NPV ≥ 0. (Keown, et. Al, 2002) [5].

2.3.2 Internal Rate of Return. The internal rate of return (IRR) is an indicator of the level of investment efficiency. According to Keown [5], IRR is one of the decisions in capital budgeting that reflects the rate of return of a project. Mathematically, IRR is the discount rate that offsets the present value of cash inflows with the present value of cash outflows.

2.3.3 Profitability Index. This method compares the value of future net cash flows with the current investment value. Profitability index must be greater than 1 (one) to be determined as feasible. The larger the PI, the more feasible the investment. According to this standard of analysis, the investment is feasible If PI > 1. If PI < 1, the investment is not feasible (Keown, et. Al, 2002)) [5].

2.3.4 Payback Period. The payback period is the number of days needed to recoup the investment costs that have been incurred through net cash flow. In general, the shorter the payback period, the better the project. Improvements in the payback period can be a good measuring tool for calculating liquidity risk in a project (Hansen, Don R., Mowen, Maryanne M. (2000)) [3].

2.3.5 Cash Flow. Cash profit is profit in the form of cash flow. In the income statement, all costs are taken into account, whether they are in cash, such as raw materials, wages, salaries, promotion costs, or others. Therefore, cash flow can be calculated by adding profit after tax with non-cash expenses (Keown, et. Al, 2002) [5].

2.3.6 Sensitivity Analysis. Sensitivity analysis is an analysis performed to determine the effect of changes in production parameters on changes in production system performance in generating profits. By conducting a sensitivity analysis, the possible consequences of these changes can be identified and anticipated in advance.

2.3.7 Monte Carlo Simulation. Monte Carlo simulation is a computer-based technique for studying the consequences of risk uncertainty in the financial sector. (Kwak dan Ingall, 2007) [1]. It is usually used as a method in the risk measurement process to produce a risk measure from the economic aspect of an investment or project. This method enables the project manager to determine alternative schedules, reserve costs, or both at once in order to avoid the worst that will happen to the project.

3 RESULTS

3.1 Investment Plan

To anticipate the problem, PT X's management tried to accelerate the process of realizing the development plan by purchasing 260 mobile towers. Subsequently, two alternatives of investment were carried out as follows:

- The alternative without purchasing mobile towers (alternative A) and,
- The alternative by purchasing mobile towers (alternative B).

Table 3: Comparison of NPV, IRR, PBP, and PI for Alternative A and Alternative B

Desc.	Alternative A	Alternative B
NPV	IDR 238,080,968,902	IDR 273,188,483,496
IRR	15.05%	13.81%
PBP	12 Years 6 Months	14 Years 10 Months
PI	1.22	1.14

3.2 Data Collecting & Processing

The data collection was carried out by distributing questionnaires and conducting interviews with employees of PT X and gathering historical data of the company. Based on the questionnaires and interviews, the variables that most influence the construction of a tower could be determined, such as tower construction costs, revenue from tower rentals, and tower maintenance costs. The data were collected to obtain data on tower construction, purchase of mobile towers, duration of work, WACC, taxes, inflation estimates, and the like in order to help calculate the cash flow.

3.3 Cash Flow Projections

After the data were collected and processed, calculations were carried out using the net present value (NPV), internal rate of return (IRR), payback period (PBP), and profitability index (PI) methods. The results of cashflow projections are as follows:
Based on the calculation results that were obtained, the analysis of these two alternatives are as follows:

- Both NPV alternatives are positive, which means that both alternatives are feasible.
- IRR is 15.05% for alternative A and 13,81% for alternative B, where the value is greater than the WACC that was set by the company, which is 11.50%. This indicates that the two alternatives meet the expectations of PT X and are feasible to run.
- In the calculation of the payback period, both alternative A and alternative B are smaller when compared to the economic life of a conventional tower, which is 20 years, so they are feasible to run.
- The feasibility requirement of a project for assessors on the profitability index is worth more or equal to 1, thus both alternatives can be said to be feasible.

However, when comparing the two alternatives, alternative B has a higher NPV than alternative A. For this reason, when viewed from the company's perspective of income, alternative B, which is to procure mobile towers, should be chosen as the best alternative.

3.4 Risk Analysis

3.4.1 Sensitivity Analysis. After determining the best alternative, which is procuring mobile towers (alternative B), the next step was to perform a sensitivity analysis on the chosen alternative. The analysis was carried out by looking at the variables that affected the NPV and IRR of the project. The variables that were analyzed were tower construction costs, revenue from tower rentals, and tower maintenance costs. Questionnaires were distributed to stakeholders or company employees who had the capability and responsibility in making decisions for the three variables. The results of the sensitivity analysis for the selected alternative can be seen in Table 4 as follows:

The results of the sensitivity analysis of the three possible changes in variables that affected NPV and IRR still showed that the selected project is feasible to run. According to the analysis, the 10% reduction in tower rental income has the smallest and most significant NPV and IRR values, thus changes in these variables deserves more attention of the company's management.

3.4.2 Monte Carlo Analysis. This simulation used a computer program to randomize the variables that were assumed to affect the NPV and IRR. This process was repeated 10,000 times. These variables were tower construction costs, tower rental income, and tower operational costs. The tower construction costs variable was assumed to experience a price change of 95% to 115%. The tower rental income variable was assumed to experience a price change of 90% to 100%. Lastly, tower operational costs variable was assumed to experience a price change of 90% to 105%. The three variables used a continuous distribution and were randomized to obtain new NPVs and IRRs.

The NPV and IRR were calculated using the results of the Monte Carlo simulation, which were randomized 10,000 times on three random variables. Table 3 contains the statistical data derived from these findings. The following explanation was taken from the simulation results:

- There is a negative NPV of the simulation results.
- There were 106 occurrences of negative values with a probability of 1.06%.
- There is an IRR value below the WACC.
- There were 103 occurrences of IRR value below the WACC, so the probability of the IRR below 11.50% is 1.03%.

4 CONCLUSIONS & RECOMMENDATIONS

This study focuses on the NPV, IRR, PBP and PI methods. The findings of these calculations were able to assist in determining if the two investment alternatives were feasible or not from a financial standpoint. Considering that this project ran for a long time, it is necessary to use sensitivity analysis and Monte Carlo simulation to analyze future situations of uncertainty. Based on the analysis that was conducted, it can be concluded that:

- The results of the project feasibility analysis from the financial aspects for the assessment of NPV, IRR, PBP and PI for both alternatives are fulfilled. However, the conventional tower construction project is more feasible to run by choosing alternative B, which is by purchasing mobile towers with

Table 4: Comparison of NPV, IRR for Sensitivity Analysis

Description	Alt. B	Tower Investment (+ 15%)	Rental Income (- 10%)	Tower Operational Cost (+ 5%)
NPV	IDR 273,188,483,496	IDR 52,716,720,810	IDR 32,915,456,511	IDR 256,817,703,702
IRR	13.81%	11.90%	11.78%	13.67%

Table 5: Simulation Statistical Data Results

Description	NPV	IRR
Minimum Value	IDR (45,219,790,509)	11.15%
Maximum Value	IDR 208,740,843,606	13.29%
Average	IDR 81,773,305,247	12.17%
Median	IDR 81,816,134,359	12.17%
Standard Deviation	IDR 35,431,409,780	0.30%

the consideration that alternative B has a larger NPV value, thus increasing the revenue for the company.

- The results of the sensitivity analysis of the three possible changes in variables that affected NPV and IRR still showed that the selected project is feasible to run. In the analysis of the 10% reduction in tower rental income, which has the smallest and most significant NPV and IRR values, the changes in these variables deserve more attention of the company's management.
- The results of Monte Carlo simulation analysis showed that the NPV value is negative for 106 times out of 10,000 trials, indicating that there is a 1.06% probability of inadequacy when looking at the NPV. According to the IRR simulation results, the IRR number is less than the company's WACC standard, which is 103 occurrences out of 10,000 trials. When considered from the perspective of the IRR value, this selected project has a probability of 1,03%. As a result, it can be inferred that alternative B has a very low chance of failure and is, therefore, feasible to run.

The study's findings led to the conclusion that alternative B would be the best option for PT X. The results of this study can be recommended to other tower providers and used to conduct further research for the procurement of future mobile towers.

REFERENCES

[1] Kwak, Y.H. dan Ingall, L. (2007). Exploring Monte Carlo Simulation Applications for Project Management. IEEE Engineering Management Review. Januari 2007.
[2] Sharpe, William F., et.al (1995). Investment.(edisi kelima). New Jersey: Pretice Hall.
[3] Hansen, Don R., Mowen, Maryanne M. (2000). Manajemen Biaya dan Pengendalian. (Buku 1Edisi Pertama). Jakarta: Salemba Empat.
[4] Jones, Charles P. (2004), Investment. New York: Prentice-Hall.
[5] Keown, Arthur J., Martin, John H., Petty, John W., Scott, David F. (2002). Financial Management Principles and Applications. New Jersey: Pretice Hall.
[6] Audriene, Dinda. (2016, 26 Agustus). Pendapatan Data Jadi Primadona Emiten Telekomunikasi. CNN Indonesia [Online]. Halaman: ekonomi/berita bisnis. Tersedia: http://www.cnnindonesia.com.

Readiness Status of Artificial Intelligence Applications on Electric Vehicles

A mini global review and analysis using the J-TRA method

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ABSTRACT

The transportation sector is a significant contributor to global greenhouse gas (GHG) emissions. It is estimated that replacing fossil fuel-based vehicles with electric vehicles (EVs) powered by sustainable and renewable energy could contribute to approximately 21% of emission avoidance by 2050. To improve the efficiency of EV operation, various artificial intelligence (AI) technologies have been applied. Examples include charging system optimization, self-driving car technology, and traffic control technology. To understand the current readiness status of those technologies applications, a small database of AI use in EVs that is in practice globally is constructed. There are 23 locations of prototype projects identified. The projects are categorized by the AI type, developer type, size of operation, and readiness status. Readiness status is analysed with the Japan Technology Readiness Assessment (J-TRA) methodology. There are seven analysed parameters: 1) Market, 2) Technology development, 3) System Integration, 4) Sustainability Verification, 5) Safety, 6) Commercialization and 7) Cost and Risk. The results show that while there is a promising market, steady progress in technological development, and verified environmental benefits, more work is needed to ensure safety and integration with the current systems before the technology can reach higher readiness levels of commercialization, cost, and risk-coping mechanisms.

CCS CONCEPTS

• **Artificial intelligence**; • **Emerging technologies**; • **Analysis and design of emerging devices and systems**;

KEYWORDS

Artificial intelligence, electric vehicle, TRA, smart grid, self-driving car

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1 INTRODUCTION

The transportation sector contributed 23% of global greenhouse gas emissions in 2019 [1]. Most nations have agreed to restrict greenhouse gas emissions and global warming to 2°C under the Paris climate agreement [2]. Although improving the vehicle operating efficiency can reduce transportation-related GHG emissions [3], it is estimated that replacing fossil fuel-based vehicles with renewable energy (RE)-based electric vehicles (EVs) could contribute to greater emission avoidance, which is approximately 21% by 2050 [4]. Moreover, recent developments show that vehicle operation efficiency improvements are also being made for EV technology.

Artificial intelligence (AI) technology has been applied to enhance EV functions, including optimizing charging systems, developing self-driving cars, and optimizing traffic control. At a higher level of abstraction, AI may improve the performance and efficiency of machines, system processes, and human–machine cooperation [5]. Improving the performance and efficiency of machine and system processes is performed by intelligent monitoring and control programs that can automatically make judgments. Using machine learning, for example, future system performance and circumstances may be predicted. Machine learning can predict EV battery driving range [6] or EV battery aging status [7]. The optimization method using AI has also been proven to enhance EV driving performance by maximizing the energy management system [8].

AI can also improve cooperation between humans and machines to improve the processing, analysis, and presentation of the machine, system, or factory data to human controllers via an interface or dashboard. A study by Lee [9] shows that AI accelerates the automation of electric vehicle driving, and the AI algorithms employed in electric cars have evolved. Qi et al. [10] incorporated reinforcement learning to improve a Hybrid EV to expand the vehicle's ability to explore the environment where it operates.

In recent years, the emergence of AI has made data-driven approaches to charging infrastructure planning more prominent. Consequently, academics began using AI approaches to handle difficulties linked with charging infrastructure design, such as the location of charging stations and the forecast of charging demand. Some of

the studies, including [11], [12], [13], [14], [15], [16], and [17], incorporated different types of AI algorithms to improve the charging strategy efficiency for EVs.

Aside from that, research related to AI as traffic control technologies also increases with the advancement and growth of EV adoption. A study by Nie and Farzaneh [18] focused on developing real-time dynamic predictive cruise control (PCC) for EVs in integrated traffic with simulated driving scenarios. Additionally, Li et al. [19] used deep reinforcement learning-based energy management in networked traffic. A deep deterministic policy gradient technique integrates vehicle reference speed planning into the energy management approach in the EV. A driver model and adaptive equivalent consumption reduction technique perform optimum power split control based on the projected reference speed at the lowest layer of AI use. Using real-time traffic information, EV traffic control management, specifically for energy management, can be maximized, as Shi et al. [20] proposed.

Aside from research conducted by academia, many industries and countries that have successfully adopted EV have also started to conduct project-based AI. To understand the current status and readiness of AI-related technology for EVs, this study builds a small-scale database of EV projects that applied AI technology. First, data is gathered from several countries and then classified based on the type of AI used, project type, size, and readiness status. Second, the Japan Technology Readiness Assessment (J-TRA) method is applied to analyse seven readiness parameters of technology readiness: market, technology development, system integration, sustainability verification, safety, commercialization, cost, and risk. The results of this study are expected to provide a better understanding of the current AI application readiness status on EVs and identify the bottleneck to accelerating the improvement of AI on the EV technology readiness level (TRL).

2 METHODOLOGY

The present study built a mini database containing projects on AI applications on EVs taking place globally. The data were categorized by its location, developer type (public, private, public–private-partnerships/PPP, or others), the type of AI use (charging system optimization, self-driving car technology, traffic control technology, or others) [9], and the general readiness level of the technology. The database was analyzed by employing the J-TRA method to identify the bottleneck of AI application on EV using seven parameters: 1) Market, 2) Technology Development, 3) System integration, 4) Sustainability verification, 5) Safety, 6) Commercialization, and 7) Cost and Risks. The research framework is summarized in Figure 1.

The outcome of a J-TRA is a TRL presented in 8 readiness levels indicating how ready the technology is, with 0 as the lowest score and eight as the highest score. A TRL 8 indicates a full readiness level where technology has reached a mass production stage, is fully integrated with the existing systems, optimally functioning with assessed risks and equipped with a risk-coping mechanism, complies with the law and regulations, and has a verified contribution of greenhouse gas (GHG) emission reduction. The J-TRA methodology was adopted from the original Technology Readiness Assessment (TRA) method developed by The National Aeronautics and Space Administration (NASA) [21]. It has been employed in

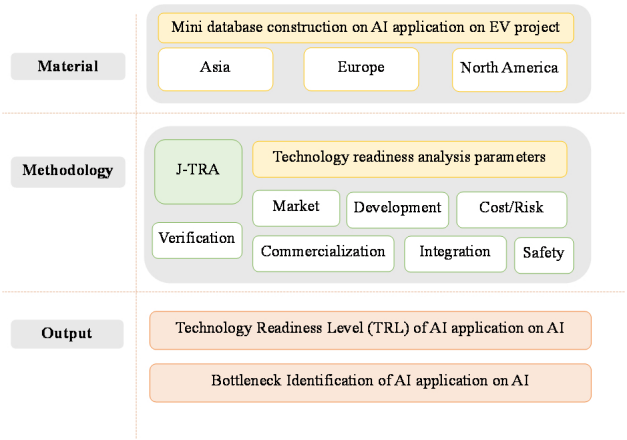

Figure 1: Research Framework

some studies in various fields, including biomass energy conversion technology assessment [22]–[24] and EV [25], [26] in various countries.

The TRL result both reports the readiness status of the technology and indicates which among the seven assessed parameters is the bottleneck of the technology. Each parameter was assessed with a compliance checklist available in a manual published by Japan's Ministry of the Environment [27]. Table 1 is the J-TRA scoring matrix that shows the number of checklists in each parameter. As the number of compliance checklists for each parameter is different, a normalization process must be conducted as expressed in Equation 1, where X_k represents the score value for parameter k, and the normalized value for parameter k is represented by N_k. The maximum value in category k or Max_k and the minimum value in category k or Min_k can be identified by the alphabet-numeric combination codes in the J-TRA scoring matrix (Table 1). The fixed value, 8, in equation (1) refers to the maximum TRL score. The parameter with the lowest compliance score is the bottlenecks of technology development and is the final TRL score (Equation 2).

$$N_k = \frac{X_k}{Max_k - Min_k} * 100\% * 8 \tag{1}$$

$$TRL_k = Min_k \tag{2}$$

The bottlenecks of each technology development must be addressed to advance towards a higher level of readiness. This study generates a TRL for each type of AI application in EV: 1. Charging system optimization, 2. Self-driving car technology, and 3. Traffic control technology.

3 RESULTS AND DISCUSSIONS

3.1 Readiness Status of AI for Charging System Optimization

By connecting an EV to a smart grid (vehicle-to-grid), an EV can act as an energy storage device [28]. The connection also allows EVs to countermeasure the intermittency of RE by supplying stored electricity when demand is higher than supply and storing electricity when supply is higher than demand. AI facilitates the mechanism

Table 1: The J-TRA Scoring Matrix [21]

TRL	A (Market)	B (Development)	C (Integration)	D (Verification)	E (Safety)	F (Commercialization)	G(Cost and risk)
1	A-1	B-1		D-1			
2	A-2	B-2		D-2			
3	A-3	B-3	C-1	D-3	E-1	F-1	G-1
4	A-4 A-5	B-4	C-2	D-4	E-2	F-2	G-2
5	A-6	B-5	C-3	D-5	E-3	F-3	G-3
6	A-7	B-6	C-4	D-6	E-4	F-4	G-4
7	The equipment and systems have been finalized. Manufacturing and introduction processes have been completed.						
8	Manufacturing and introduction processes have been completed and are in mass production of products.						

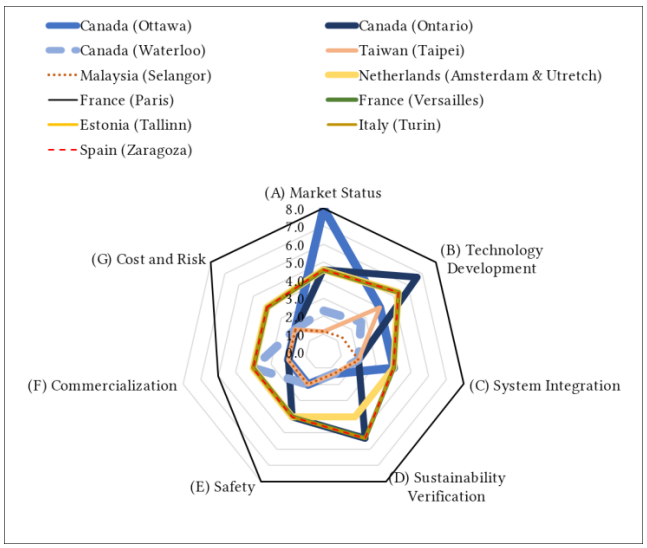

Figure 2: Technology Readiness Level of AI for Charging System Optimization

by collecting information through sensors and devices on a real-time basis and taking control of the battery charging system based on rapid assessment [9].

There are 11 locations of AI for charging system optimization projects collected in our database (Figure 2). Many of them are located in Canada and some European countries, such as France, Estonia, Spain, the Netherlands, and Italy. There is also evidence from Asian countries such as Malaysia and Taiwan. The market parameter of the project in Ottawa, Canada, has the highest readiness status. A pilot project supported by a PPP mechanism provides funding for grid efficiency improvement innovation projects [29]. Regulated private companies, such as an electricity distribution company, are already involved in the project. Therefore, the market and distribution system are already fully established. The safety parameter has the lowest TRL score, and it is the lowest score for many other AIs for charging system optimization projects. Potential hazards such as fire, leakage, explosion, and cybersecurity issues should be assessed. The system must be equipped with countermeasure equipment to reach the higher TRL in this parameter.

The projects in Europe are run by one company [30] that develops EV charging systems using AI for different purposes: 1) regional load aggregation, 2) two-way charging at the community level, and 3) intelligent charging for private car parks. The one in France has a high overall TRL. It is an inductive loading lane where buses can be charged when waiting at the city's traffic lights. The one in the Netherlands is a two-way charging system for a car-sharing company where the car operation time is relatively shorter, and the parking time is longer. The charging takes place when the car is parked at a designated place. Such a charging management system is also applied for private cars.

3.2 Readiness Status of AI for Self-driving Car Technology

Self-driving car technology includes a camera, image detection, and visual. The self-driving car projects collected in the database are located in Asia, such as Dubai and Japan. For example, Dubai is collaborating with a British company to develop a "sky pod" transit system, which is "a cross between a monorail and ski lift" [31], [32]. Each pod can transport four passengers at 50 km/h, entirely operated by AI. The project has gained much interest from the market sector but is still in the feasibility study stage.

The self-driving car project in various locations in Japan is under one project monitored by the Ministry of the Environment [33]. A driverless passenger vehicle with only four passenger capacities and a speed of 20 km/h is operated on a pilot mode in several cities and towns in Japan. The project is referred to as "green slow mobility" and aimed to operate as an existing public transportation feeder and potential tourism enhancement strategy.

The parameters with the lowest TRLs for self-driving car technology are cost, risk, and commercialization (Figure 3). A survey of pilot project participants in Japan revealed that people are willing to pay a minimum fee for the service, such as 100 or 500 JPY (approximately 1 to 5 dollars), a one-coin payment in the Japanese currency. However, whether such a fee can cover the cost of operation and maintenance of the self-driving car over time has to be investigated.

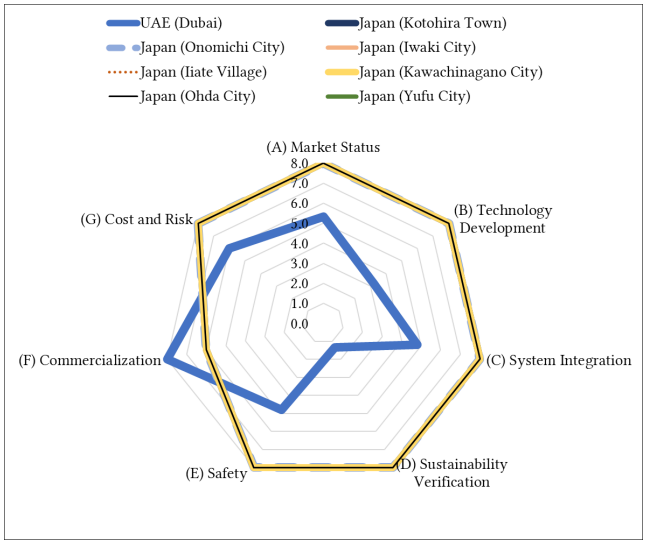

Figure 3: Technology Readiness Level of AI for Self-driving Car Technology

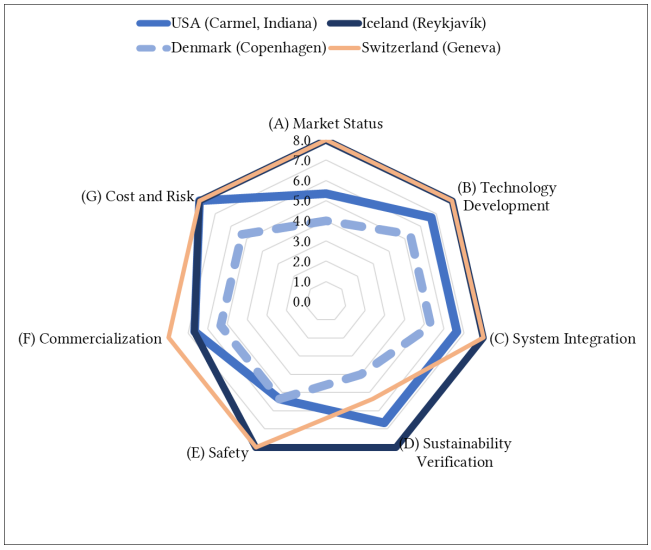

Figure 4: Technology Readiness Level of AI for Traffic Control Technology

3.3 Readiness Status of AI for Traffic Control Technology

Traffic control can be optimized by using AI. For example, in Carmel, USA, a PPP pilot project uses traffic data captured by a surveillance camera in public spaces to understand the road use pattern and utilize it for traffic flow optimization strategies and support emergency procedures [34]. However, the technology lacks sensors for nonregular objects, such as the sudden appearance of wild animals, which may obstruct the strategies. Equipping the technology with a nonregular object identification function may improve the safety score within the TRL parameters.

In Geneva, Switzerland, AI is used to optimize the parking system. Sensors are planted in parking areas, resulting in drivers quickly finding a free parking slot nearby. This service reduces traffic congestion and time spent on the road while looking for an available parking area. This technology is in full operation and is rapidly expanding across Europe and the Asia-Pacific region [32], [35] (Figure 4).

Copenhagen, Denmark, is implementing a pilot project for intelligent streetlights and traffic signals. For example, prompted by sensors, bright streetlights are provided for cyclists approaching a dark intersection to reduce the risk of accidents. Traffic signals are also regulated with AI so that buses are given priority over personal passenger cars in traffic lights. Moreover, cyclists do not have to stop at red lights so that they do not have to inhale too much air pollution caused by combustion engine vehicles. These solutions are on a pilot project stage where monitoring equipment is reinstalled, and tests are being carried out to identify the best solution for a safe and efficient traffic flow [32], [36].

4 CONCLUSION

There is a global movement toward mobility electrification, as it can mobilize the transportation sector towards a clean energy transition. Research and technology development have been conducted in various sectors to improve EV use efficiency. AI has been explored and applied for EVs mainly for charging system optimization, self-driving car technology, and traffic control strategies.

The present study built and analysed a mini database of AI applications on EV projects globally on a small scale as a preliminary attempt to understand the technologies' current status and identify the bottlenecks for accelerating progress towards higher readiness levels.

It was found that some projects' AI applications for traffic control have reached a high readiness status, especially for parking system improvement. AI use for self-driving car technology is at a demonstration project level in Japan and under a feasibility study status in Dubai. While AI for a self-driving car is a fascinating idea, further study must be done to ensure the cost and risk of such technology and whether it meets the demand and needs of the targeted market. The present study hypothesizes that it may be suitable for a particular market niche, such as the tourism industry and short-distance mobility, for ageing and depopulating small towns.

AI application to charging system optimization seems suitable for smart cities/communities where the smart-grid system is implemented. Like many components of smart-grid projects, commercialization is the bottleneck of such projects to reduce costs and allow mass production. In addition, addressing safety issues such as hazards, and cybersecurity may allow such projects to progress further in the overall readiness level.

The limitation of this study is the minimum scale of the database. Further study with a more extensive database is necessary to better understand the global status of AI application EVs. Several other avenues for future studies are 1) social needs assessment for smart mobility in tourism, depopulating or aging communities, 2) safety system development for intelligent traffic signals, and 3) upgrade of cybersecurity, laws, and regulations to accommodate smart communities and its components.

ACKNOWLEDGMENTS

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REFERENCES

[1] International Energy Agency, "CO2 Emissions from Fuel Combustion 2019," 2019. DOI: https: //doi.org/https: //doi.org/10.1787/2a701673-en.
[2] J. Rogelj *et al.*, "Paris Agreement climate proposals need a boost to keep warming well below 2 °C," Nature, vol. 534, no. 7609, pp. 631–639, 2016, DOI: 10.1038/nature18307.
[3] L. Cozzi and T. Gould, "World Energy Outlook 2021," 2021. [Online]. Available: www.iea.org/weo.
[4] International Energy Agency, "Global EV Outlook 2021 - Accelerating ambitions despite the pandemic," 2021.
[5] J. Eager, M. Whittle, J. Smit, G. Cacciaguerra, and E. Lale-demoz, "Opportunities of Artificial Intelligence Policy," Ipol, vol. 1, no. 6, pp. 1–99, 2020.
[6] S. Sun, J. Zhang, J. Bi, and Y. Wang, "A Machine Learning Method for Predicting Driving Range of Battery Electric Vehicles," J. Adv. Transp., vol. 2019, p. 4109148, 2019, DOI: 10.1155/2019/4109148.
[7] Y. Zhang, T. Wik, J. Bergström, M. Pecht, and C. Zou, "A machine learning-based framework for online prediction of battery ageing trajectory and lifetime using histogram data," J. Power Sources, vol. 526, p. 231110, 2022, DOI: https: //doi.org/10.1016/j.jpowsour.2022.231110.
[8] G. Brückmann, F. Willibald, and V. Blanco, "Battery Electric Vehicle adoption in regions without strong policies," Transp. Res. Part D Transp. Environ., vol. 90, no. December 2020, p. 102615, 2021, DOI: 10.1016/j.trd.2020.102615.
[9] M. Lee, "An analysis of the effects of artificial intelligence on electric vehicle technology innovation using patent data," World Pat. Inf., vol. 63, p. 102002, 2020, DOI: https://doi.org/10.1016/j.wpi.2020.102002.
[10] C. Qi *et al.*, "Self-supervised reinforcement learning-based energy management for a hybrid electric vehicle," J. Power Sources, vol. 514, p. 230584, 2021, DOI: https://doi.org/10.1016/j.jpowsour.2021.230584.
[11] S. Abdullah-Al-Nahid, T. A. Khan, M. A. Taseen, T. Jamal, and T. Aziz, "A novel consumer-friendly electric vehicle charging scheme with vehicle to grid provision supported by genetic algorithm based optimization," J. Energy Storage, vol. 50, p. 104655, 2022, DOI: https://doi.org/10.1016/j.est.2022.104655.
[12] S. I. Spencer, Z. Fu, E. Apostolaki-Iosifidou, and T. E. Lipman, "Evaluating smart charging strategies using real-world data from optimized plugin electric vehicles," Transp. Res. Part D Transp. Environ., vol. 100, p. 103023, 2021, DOI: https://doi.org/10.1016/j.trd.2021.103023.
[13] R. Wang, J. Mu, Z. Sun, J. Wang, and A. Hu, "NSGA-II multi-objective optimization regional electricity price model for electric vehicle charging based on travel law," Energy Reports, vol. 7, pp. 1495–1503, 2021, DOI: https://doi.org/10.1016/j.egyr.2021.09.093.
[14] X. Yang *et al.*, "A bi-level optimization model for electric vehicle charging strategy based on regional grid load following," J. Clean. Prod., vol. 325, p. 129313, 2021, DOI: https://doi.org/10.1016/j.jclepro.2021.129313.
[15] M. A. Hamida, R. A. El-Sehiemy, A. R. Gindi, E. Elattar, and A. M. Shaheen, "Parameter identification and state of charge estimation of Li-Ion batteries used in electric vehicles using artificial hummingbird optimizer," J. Energy Storage, vol. 51, p. 104535, 2022, DOI: https://doi.org/10.1016/j.est.2022.104535.
[16] G. Zhou, Z. Zhu, and S. Luo, "Location optimization of electric vehicle charging stations: Based on cost model and genetic algorithm," Energy, vol. 247, p. 123437, 2022, DOI: https://doi.org/10.1016/j.energy.2022.123437.
[17] X. Li and A. Jenn, "An integrated optimization platform for spatial-temporal modeling of electric vehicle charging infrastructure," Transp. Res. Part D Transp. Environ., vol. 104, p. 103177, 2022, DOI: https://doi.org/10.1016/j.trd.2022.103177.
[18] Z. Nie and H. Farzaneh, "Real-time dynamic predictive cruise control for enhancing eco-driving of electric vehicles, considering traffic constraints and signal phase and timing (SPaT) information, using artificial-neural-network-based energy consumption model," Energy, vol. 241, p. 122888, 2022, DOI: https://doi.org/10.1016/j.energy.2021.122888.
[19] J. Li, X. Wu, S. Hu, and J. Fan, "A Deep Reinforcement Learning Based Energy Management Strategy for Hybrid Electric Vehicles in Connected Traffic Environment," IFAC-PapersOnLine, vol. 54, no. 10, pp. 150–156, 2021, DOI: https://doi.org/10.1016/j.ifacol.2021.10.156.
[20] D. Shi, S. Liu, Y. Cai, S. Wang, H. Li, and L. Chen, "Pontryagin's minimum principle based fuzzy adaptive energy management for hybrid electric vehicle using real-time traffic information," Appl. Energy, vol. 286, p. 116467, 2021, DOI: https://doi.org/10.1016/j.apenergy.2021.116467.
[21] I. Ihara, A. H. Pandyaswargo, and H. Onoda, "Development and the Effectiveness of the J-TRA: A Methodology to Assess Energy Technology R&D Programs in Japan," EcoDePS 2018 Proc., pp. 109–117, 2018, [Online]. Available: https: //researchmap.jp/?action=cv_download_main&upload_id=219915.
[22] I. Ihara, A. H. Pandyaswargo, and H. Onoda, "The Readiness Levels of Japan Supported Biomass Energy Conversion Technology Development Projects in Emerging Southeast Asia: Verification of the J-TRA Results," Sustain. Prod. Life Cycle Eng. Manag., pp. 541–555, 2021, DOI: 10.1007/978-981-15-6775-9_36.
[23] I. Ihara *et al.*, "Technology Readiness Assessment of Biomass Energy Projects using J-TRA method: Application on Southeast Asian Countries," 2019
[24] A. H. Pandyaswargo, D. Pang, I. Ihara, and H. Onoda, "Japan-Supported Biomass Energy Projects Technology Readiness and Distribution in the Emerging Southeast Asian Countries: Exercising the J-TRA Methodology and GIS," Int. J. Environ. Sci. Dev., vol. 11, no. 1, pp. 1–8, Jan. 2020, DOI: 10.18178/ijesd.2020.11.1.1217.
[25] A. H. Pandyaswargo and M. F. N. Maghfiroh, "The Readiness of Electric Vehicle in Indonesia Based on the Perceptions of Key Stakeholders," in The sixth applied science and engineering conference, 2021.
[26] M. F. N. Maghfiroh, A. H. Pandyaswargo, and H. Onoda, "Current Readiness Status of Electric Vehicles in Indonesia: Multistakeholder Perceptions," Sustainability, vol. 13, no. 23. 2021, DOI: 10.3390/su132313177.
[27] Japan Ministry of Environment, "TRL Calculating Tool Manual (3rd Edition)," 2016.
[28] E. S. Rigas, S. D. Ramchurn, and N. Bassiliades, "Managing Electric Vehicles in the Smart Grid Using Artificial Intelligence: A Survey," IEEE Trans. Intell. Transp. Syst., vol. 16, no. 4, pp. 1619–1635, 2015, doi: 10.1109/TITS.2014.2376873.
[29] Smart Energy International, "AI pilot to ease EV electricity demand - Smart Energy International," Apr. 2022. https://www.smart-energy.com/industry-sectors/electric-vehicles/ai-pilot-to-ease-ev-electricity-demand/ (accessed May 30, 2022).
[30] INCIT-EV, "INCIT-EV Project | Demonstrations of the EV recharging around Europe," 2020. https://www.incit-ev.eu/ (accessed Jun. 01, 2022).
[31] AK, "Dubai Sky Pod Transport System: Stations, Map & more - MyBayut," Roads and Transport Authority, 2022. https://www.bayut.com/mybayut/dubai-sky-pod-transport-system/ (accessed Jun. 02, 2022).
[32] D. Diran, A. F. Van Veenstra, T. Timan, P. Testa, and M. Kirova, "Artificial Intelligence in smart cities and urban mobility," 2021. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/662937/IPOL_BRI(2021)662937_EN.pdf (accessed May 31, 2022).
[33] Reconstruction Survey Design Co Ltd, "Demonstration Project of Green Slow Mobility utilizing IoT," Mar. 2020. .
[34] Volkswagen, "Volkswagen software for smart cities: Artificial intelligence improves flow of traffic | Shaping Mobility Hub," May 2022. https://re-how.net/all/1481937 (accessed May 20, 2022).
[35] Parking network, "Smart Parking, an Innovative and Ambitious Program for the Canton of Geneva," Jun. 2017. https://www.iemgroup.com/smart-parking-an-innovative-and-ambitious-program-for-the-canton-of-geneva (accessed May 30, 2022).
[36] Kopenhagen Kommune, "8 New Intelligent Traffic Solutions," pp. 1–20, 2014.

Malicious traffic analysis using Markov chain

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ABSTRACT

A massive increase in cyber attacks during pandemics has made enterprise organizations around the world strive to find new ways to comprehend and detect unknown threats. A firewall has been devised specifically for these tasks, warding off external attacks on the enterprise perimeter network. Our research aims to identify these possible intrusions through firewall traffic analysis based on the Markov chain state transition graph. The research results show that our methods can clearly distinguish malicious traffic from anomaly traffic.

CCS CONCEPTS

• **Security and privacy → Firewalls**; • **Networks → Firewalls**; **Denial-of-service attacks**.

KEYWORDS

Firewall Attacks, Graph based analysis, Markov Chain Analysis, Threat Analysis, Traffic analysis

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1 INTRODUCTION

FBI [8] has reported a rise of more than 300% cyber attacks since the pandemics as more and more corporate workers work from home . In addition, Walter[26] mentioned that cyber security efforts shifted to protecting employees working from home, leaving corporate networks more vulnerable to cyber-attacks. Furthermore, corporate employees need to be retrained to better understand cyber security threats they are facing as they work from home.

Corporations have been equipping their security perimeter using Firewall, Intrusion Detection/Prevention System (IDPS), Honeypots and other gateway protection devices to both detect and protect external cyber security attacks based on rules provided both by vendors and network administrators. It is important to note that these cyber security attacks can be detected and blocked whenever the patterns of the attacks are known and rules are ready in these security perimeter devices.

Several researchers [2, 3] investigated markov model to detect common cyber security intrusions using IDS. Ryandy et al [5, 20] discussed the unique security threat categories and threat actor's behaviors detected using honeypots. Even with these capabilities, unknown security threats, as described by Flowmon[9], contain malicious traffic patterns not yet available in the security perimeter protection devices that flow freely undetected in and out corporate networks.

We argue that there are potentially many unknown and possibly malicious traffic that flow through firewall even though it is considered an impenetrable security device as mentioned by Saltzer et al [21]. Furthermore, Chomsiri et al [4] also described various limitations of firewall that may impact performance of firewall in their research. Our research focuses on the exploration of network traffic that flows through the firewall.

The contributions of our research are as follows:

- A new framework based on markov model of analyzing unknown threat to discover malicious traffic that flows through firewall.
- Graph Analysis using network traffic flow state transition model is introduced to help validate different possible cyber security threats.

The malicious traffic discovery could help enterprise organization to further reduce the possible business risks impacted.

The remainder of this paper is organized as follows: Section 2 describes previous works related to this paper. Section 3 explains our research framework. Section 4 and 5 present the experiment setup and experimental results. Finally, section 6 concludes our research findings.

2 RELATED WORKS

2.1 Firewall

NIST 800-41r1 [22] defines firewalls as "hardware or software that manages network traffic flow across hosts or networks with various security devices." Traditionally, firewalls were installed in front of the network border. Internal hosts were secured to some extent, but most occurrences and types of assault were missed, and assaults directed from one internal host to another largely bypassed network firewalls. As a result, network designers are progressively extending firewall capabilities beyond the network perimeter to provide an extra layer of security and to protect mobile devices linked to external networks directly.

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2.2 Intrusion Detection and Prevention System

IDPS is defined as a security service that monitors and analyzes network or system events in order to detect and warn of attempts to access system resources in an illegal way in real time or near real time [24]. Furthermore, Hock et al[12] contrasted the IDPS and firewall: firewall simply looks at the packet and/or segment headers (network and transport layer), while IDPS look at the payload (application layer). In addition, Jadidoleslamy et al[13] highlighted one of the IDPS weakness is its inability to eavesdrop on and analyze high-volume, high-speed traffic resulting non-real time detection.

2.3 Log Analysis

Log analysis is the techniques used to study and understand computer-generated texts on the events of interest [15]. Various programmable technology, such as network devices, operating systems, and applications, create log data. These log files from various devices are stored in a log collector via an active secure network for future investigation. By investigating a log, a chronologically organized collection of alerts or messages that provide information about what's going on in a system, one can gain insight into the system's inner workings.

2.4 Graph

Essam et al [7] described graph theory, a discipline of mathematics, as the study of lines and points that is used to graphically represent mathematical ideas. The theory also allows one to study the relationship between lines, also called edges, and points, also called vertices. Thus, a graph can be described formally using as a pair (V, E), where V denotes a finite number of vertices and E denotes a finite set of edges.

2.4.1 State Transition Diagram. As specified by Jia et al[14] in 2013, state transition diagram depicts all of an object's conceivable states, as well as the events that cause it to change state (transitions), the conditions that must be completed before the transition can occur (guards), and the activities that occur across the object's lifespan (actions). Diagrams of state-transition are highly useful for representing the behavior of certain objects across the board. They are impacted by a large number of use cases. State-transition diagrams are diagrams that show how states change over time. The collaboration of things that cause transitions is ineffectively shown.

2.4.2 Markov Chain. Douc et al [6] describes a Markov Chain as a mathematical system that uses probabilistic criteria to shift from one state to another. The probable future states of a Markov chain are fixed, regardless of how the process got at its current state. To put it another way, the current state of affairs and the length of time that has passed define the possibility of a transition to any particular condition. Alahmadi et al [1] used markov chain to model the bot network flow behavior to provide a privacy-preserving bot detection system.

2.5 Threat Detection

Several efforts have been made for solving the issues of elimination of traffic threats. Pandeswari et al [19] presented Hypervisor Detector, a hybrid algorithm-based anomaly detection system. The proposed system is put to the test against the Naive Bayes classifier along side Classic Artificial Neural Network (ANN) algorithm inside the cloud simulator known as cloudsim 3.0. The datasets for testing are sourced from DARPA KDD Cup 1999, which classifies attack methods as DOS, probing, and so forth, including privilege escalation and remote to local (R2L). This Study contributes, by establishing a Hypervisor Detector anomaly detection system at the monitor layer for virtual machines FCM-ANN. In addition, Gandotra et al [10] demonstrated how to use Iptables to mitigate Cross-Site Scripting (XSS), FTP Flood, FTP Bounce, HTTP Flood, and SQL injection attacks. The methodology of the paper includes identifying keywords and procedures for simulating attacks, formulating Iptables rules with the intent of detecting and mitigating attacks using discovered keywords, and evaluating the performance of Iptables rules in terms of detection and mitigation of application layer attacks using the keywords discovered. On the other hand, Li et al [16] improved Apriori technique and introduced method for analyzing network attack traces by utilizing Web logs, and mining attack traces, in which the results may assist the forensic investigation.

2.6 Related works

Lubna et al [17] demonstrated anomalies reduction using dynamic rule re-ordering. Gutierrez et al [11] discussed a technique that uses tabulated vectors to produce meaningful state vectors from time-oriented blocks, to enhance the analyst's capacity for discovering events that can be used for cyber forensics. On the other hand, Li et al [16] presented a method for forensic investigation and attack source tracing, mining attack traces from online application logs, and analyzing network attack traces utilizing Web logs. Our research focus on the firewall safeguard analysis by utilizing graph analysis to uncover the suspicious and malicious traffic from the bulk traffic.

3 RESEARCH FRAMEWORK

Figure 1: research framework

Figure 1 shows our research framework which is based on NIST 800-92 [15] and NIST 800-94 [23], which starts with log generation process from the data source and ends with log disposal.

3.1 Log Generation

Network device log such as firewall log is usually generated in large quantity due to the high volume of network traffic nature. These logs are sent to the log storage system (discussed in the next section) to collect all the logs.

3.2 Log Storage

The acquired firewall log will be stored into the data repository, which will be further processed. At this phase the sub phases included as well are log rotation where the data entered into the repository is a stack where the most recent data will be prioritized,

Log archival done after rotation, data that is 3 months old must be archived which is intended to reduce the storage load on the repository server, Log reduction happen to data that is 3 months old after being compressed must be released from the server repository. Where this is done because the data has been compressed and the data in the server repository will be considered no longer needed, Log normalization where data that has been stored must go through normalization which includes adding a service name based on the service port. Also, made adjustments to the data according to the data required for graph analysis.and finally log file integrity checking where the process for performing integrity checks is obtained from the agent log where the agent log contains a key named source which has a value in the form of data source.

3.3 Log Analysis

This step is when the data from the data storage will go through the data analysis procedure. Event correlation will be used to create an event collection and grouping based on events. At this point, normal and abnormal occurrences will be identified, as well as event groupings. The analyst can be notified to make it easy for him or her to figure out which events are typical and which ones are not. Log Analysis consist of several sub phase in which Event correlation is a strategy for understanding a huge number of occurrences and identifying the ones that are truly significant among them. This is done by searching for and evaluating connections between occurrences. After the event correlation is done, a log viewing will be carried out where this is to check the contents in the log where the event correlation has been carried out. The final process of the log analysis are Log reporting where the log will be checked and if there are strange things that have not been registered, reporting will be done.

3.4 Detection Capability

If an abnormal event alert is received at this point, the analyst will attempt to examine the abnormal event to understand the abnormal event and categorize it according to appropriate event. Following the analysis step, the analyst will attempt to construct the appropriate rules for usage in the firewall to protect the firewall from assaults with similar characteristics. Detection capability will commence with following parameter for type of events detected (Well known internal port, Firewall state transition, TCP Flag state transition and Graph based analysis). For the detection accuracy there are several ways to determine how accurate the level of detecting malicious traffic is. Several ways to detect accuracy are by using threshold, blacklist and whitelist, as well as alert setting. In this research we use blacklists and whitelists to sort out IPs and ports in the system. Is it able to accept connections from outside or can only receive traffic from within. Last process of the detection capability are tuning and customization, that will be carried out on the list of allowed IPs and ports. This minimizes the discovery of ports and IPs that are not found so that they can improve detection accuracy in finding truly suspicious traffic.

3.5 Log Disposal

When data reaches the repudiation limit, it will go through a series of processes to ensure that data storage difficulties are avoided. The procedure is as follows: Data that has been stored for more than a month will be transferred to another repository for analysts to review in case further inquiry is required. If the data has been collected for more than three months, it will be compressed into JSON format and saved on the storage server.

4 EXPERIMENT SETUP

Following are specification of our Hardware setup and also Software setup. The experiment setup are shown on Figure 2.

Hardware Setup:

- Processing Server (12x Intel Xeon(R) E5-2620, 256GB DDR4)
- Forwarding PC (Core i7, 16GB RAM, 1TB HDD)
- Virtual Machine
  - Elastic Stack (16GB RAM, 4vCPU, 1TB HDD, Linux 18.04)
  - Graphviz (4GB RAM, 2vCPU, 200GB HDD, Linux 18.04)

Software Setup:

- Server Repository = Elastic Search, Kibana
- Forwarding PC = Logstash, Syslog server
- Firewall = Opnsense

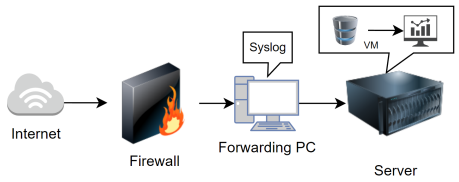

Figure 2: System Overview

5 EXPERIMENT RESULTS

5.1 Data Collection

The data comes from the opnsense firewall in which there is traffic from every host connected to the internet. The data will be collected using agent and in the data collection/ generation step there is several substep that need to be done before the data can reach the repository or continue to the data storage step. In this research the data are collected from 1st of November 2021 until 30th of November 2021.

5.2 Traffic scoring

Treurniet et al [25] explained that there are several TCP flags that deemed as normal and other than that normal flag is considered bad flags as shown on Table 1 and the weighting of those flag will be presented on Table 2 normal side. While the other TCP Flag such as SEC, RA, SAE, FPA, SAEC and SAC will be considered as bad flag. Table 2 shows normal and suspicious for each of the flags and its relevant weighting. TCP length is supposed to be limited at 40, any number larger than 40 will be considered malicious as shown on Table 3. This parameters follow closely the results presented by Mahoney[18] with TCP packet size consists of the IP header's 20 bytes and the TCP header's 20 bytes, and the first 8 bytes of the application payload. TCP options are normally included in the first four bytes of a TCP SYN (request to open) packet, in which the application data would go. Finally, Table 4 presents the firewall

Table 1: TCP Flags [25]

Event Label	Event Description
S	Request to open connection
SA	Agree to open connection
A	Acknowledgement of receipt
F	Request to close connection
R	Tear Down connection
Others	Bad Flags

Table 2: TCP Flag & Weight (Normal & Suspicious)

Normal		Suspicious	
TCP Flag	Weight	TCP Flag	Weight
S	5	SEC	10
SA	5	RA	10
R	5	SAE	10
A	5	FPA	10
FA	5	SAEC	10
F	5	SAC	10
		PA	10

Table 3: TCP Length and weight parameters

TCP Length	Weight
length = 0	3
length >0 && length <48	5
length >48	10

Table 4: Firewall Action Weight

Action	Weight
Pass	5
Block	10

action and its relevant weight, used by the firewall to act on the incoming packets and filter the packet, i.e. pass or block the packet, based on the given rules.

Based on the given weight table, the traffic scoring formula to determine the suspicious and benign traffic is as follow:

$$Score = (0.125 * TCPFlagweight) + (0.125 * TCPLength) + (0.25 * Action) \quad (1)$$

- 0.25 because the TCP flag may be suspicious so there is a need for the multiplication that can differentiate each flag to separate the status.
- 0.25 multiplications to differentiate the length
- 0.5 due to the weight of action are crucial to differentiate pass traffic and block traffic other than tcp flag. So, in this case the action will be the big determiner.

5.3 Firewall attacks

5.3.1 TCP SYN Flood attack. or better known as half-open attack is a type of denial-of-service (DDoS) attack which objective is to make a server unavailable to the legitimate traffic by populating all accessible server assets. By repeatedly sending initial connection request known as (SYN) packets, the attacker is capable to overwhelm all available ports on a targeted server machine, rendering the targeted device, respond sluggishly to the legitimate traffic or not respond at all.

5.3.2 TCP Padding SYN-ACKS attack. A SYN-ACK flood is a type of attack that includes delivering a large number of faked SYN-ACK packets to the target server. Because it takes a lot of processing resources for a server to figure out why it's getting out-of-order packets. The contents of a SYN-ACK packet are beyond the control of an attacker. While we've observed padded SYN floods for years, we didn't expect to see a padded SYN-ACK. When SYN-ACK assaults were carried out in the real world, packets arriving at the victims' networks had a predictable length of 44 bytes. As previously stated, this indicates that the attackers were most likely sending out 40-byte optionless SYN packets, with the MSS options set by on-path networking hardware in route.

5.3.3 SYN-ACK Amplification. SYN-ACK attacks can provide a small degree of amplification, but this can be increased by targeting IP space that is allocated but unused (i.e., the IP is routable but no machine is currently deployed and/or managing network traffic). As a result of this circumstance, attackers can completely exploit TCP retransmission attempts, increasing amplification factors and bandwidth use. A regular machine will react with a RST packet when it gets an out-of-state SYN-ACK from a reflector. The reflector will receive this RST message, and the TCP connection on the reflector will be terminated. The SYN-ACK packet will be routed (impacting the networking gear along the way) but never reach a real machine that would send a RST if it is headed for an IP address that is assigned but unused. Due to the lack of a RST packet, the reflector will presume that the SYN-ACK was not sent and will try to do retransmission.

5.3.4 TCP-Starvation. TCP incorporates certain congestion control methods since it is a trustworthy protocol. One of these is Slow Start. TCP senders start with a modest (congestion) window size while transferring data. It does so because it is unknown if the data being delivered will be received successfully at the receiving end (sender gets to know when acknowledgments are received). The value (size) of the (Congestion) Window is increased when the sender gets an acknowledgment (ACK) for the data delivered. With each acknowledgment (ACK) received, it will do so. This sender's transmission rate will be increased until a loss is discovered, such as when the sender does not get an ACK from the receiver. When this occurs, TCP (on the sender) believes that the network is congested (that is why the data was not delivered or ACKed). It replies by lowering the amount of data it delivers over the network. TCP is used because it is dependable and focuses on connections. UDP, on the other hand, is a connectionless protocol that is unstable and has any flow or congestion management measures. It just sends data with the best effort possible. Since UDP is unaware that the network is congested, it has no way of slowing down or lowering the amount of data transferred.

5.4 State transition diagram and Markov Chain

5.4.1 TCP SYN Flood attack. Figure 3 show the representation of the TCP Syn Flood attack in the State transition diagram where in here, we can see that the SYN traffic coming to the server will be massive and the traffic will either passed or blocked, block happen due to the firewall reach certain threshold and close the connection of the traffic. On the other hand, if the traffic passed, it will not do anything till the timeout reached and the connection will be closed; Thus, it is called Syn Flood attack. The attack also reflected on the Figure 4 where it's a markov representation and show the weight of the attack probability to the next phase.

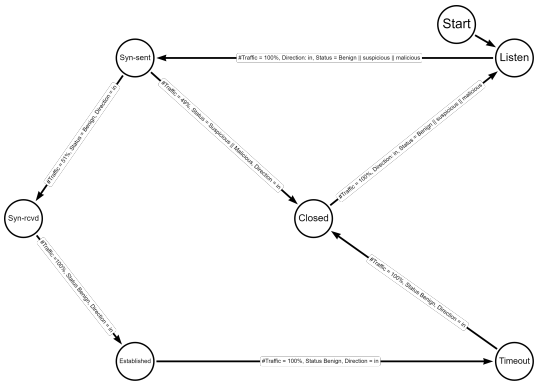

Figure 3: State Transition Diagram for TCP SYN Flood Attack

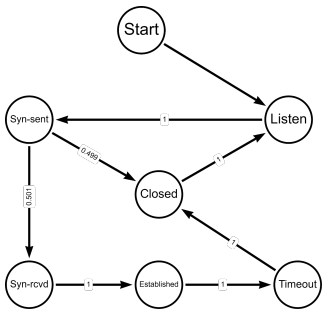

Figure 4: Markov representation for TCP SYN Flood Attack

5.4.2 TCP Padding SYN-ACKS attack. This traffic of this attack will never reach the established phase, shown on Figure 5. This attack connection will always be blocked due to the non regulated TCP connection. The markov representation of this attack are shown on the Figure 6.

5.4.3 Syn-Ack Amplification. This attack uses a very small level of amplification, as shown in Figure 7, but it is feasible to enhance the amplification factor by targeting IP space that is assigned but vacant. This attack happen when normal machine received out-of-state SYN-ACK Flag the machine will replied with RST and this will cause the computer to think that the SYN-ACK was not sent and commence retransmission efforts, and amplified the traffic. The markov representation are shown on the Figure 8.

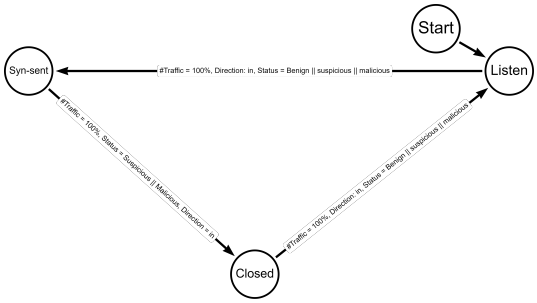

Figure 5: State Transition Diagram for TCP Padding SYN-ACKS attack

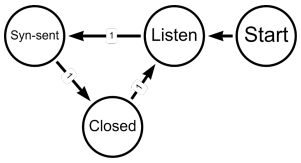

Figure 6: Markov Diagram for TCP Padding SYN-ACKS attack

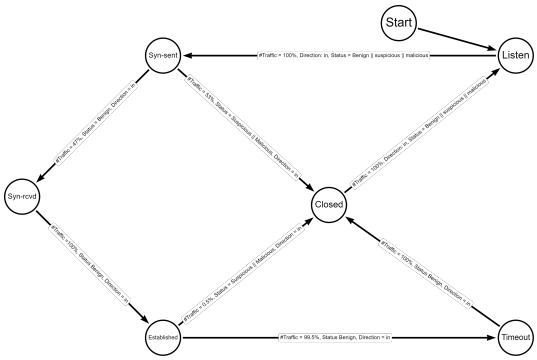

Figure 7: State Transition Diagram for Syn-Ack Amplification

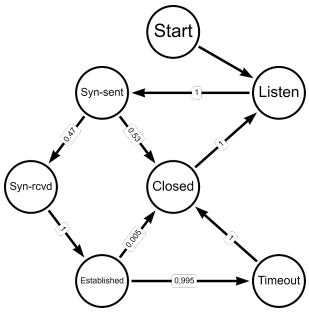

Figure 8: Markov Diagram for Syn-Ack Amplification

5.4.4 TCP-Starvation. TCP traffic pauses (slow start) to deal with lost traffic, whereas UDP traffic does not, resulting in UDP packets filling queues and depleting TCP of bandwidth. As shown on Figure

9, there is no issues on the traffic up to the connection closing the client will not be able to send the FIN flag to disconnect the connection. Resulting the server waiting up until the timeout, the server will try to send the connection to make sure the package arrive. The representation of the matrix TCP Starvation are shown on Figure 10.

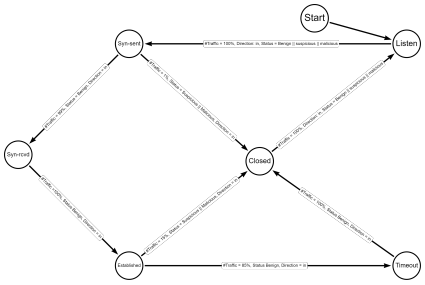

Figure 9: State Transition Diagram for TCP-Starvation

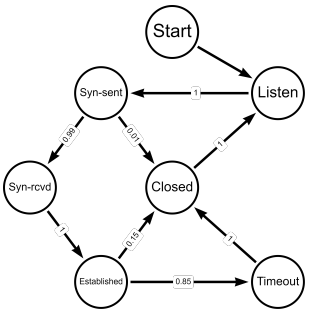

Figure 10: Markov Diagram for TCP-Starvation

6 CONCLUSION

Network traffic analysis framework based on Markov model to detect malicious traffic are introduced, which utilize the core of Markov that is state transition diagram and weighting.Using graph analysis based on the Markov model, various TCP-based security attacks can be detected, hence subsequent corporate security posture could be improved by blocking this malicious traffic. Our future research will explore the possibility of automate the discovery of malicious traffic in the enterprise security perimeter.

REFERENCES

[1] Bushra A Alahmadi, Enrico Mariconti, Riccardo Spolaor, Gianluca Stringhini, and Ivan Martinovic. 2020. BOTection: Bot detection by building Markov Chain models of bots network behavior. In *Proceedings of the 15th ACM Asia Conference on Computer and Communications Security*. Association for Computing Machinery, 652–664. https://doi.org/10.1145/3320269.3372202

[2] Davide Ariu, Roberto Tronci, and Giorgio Giacinto. 2011. HMMPayl: An intrusion detection system based on Hidden Markov Models. *computers & security* 30, 4 (2011), 221–241. https://doi.org/10.1016/j.cose.2010.12.004

[3] André Årnes, Fredrik Valeur, Giovanni Vigna, and Richard A Kemmerer. 2006. Using hidden markov models to evaluate the risks of intrusions. In *International Workshop on Recent Advances in Intrusion Detection*. Springer, 145–164. https://doi.org/10.1007/11856214_8

[4] Thawatchai Chomsiri, Xiangjian He, and Priyadarsi Nanda. 2012. Limitation of listed-rule firewall and the design of tree-rule firewall. In *International Conference on Internet and Distributed Computing Systems*. Springer, 275–287. https://doi.org/10.1007/978-3-642-34883-9_22

[5] Ryandy Djap, Charles Lim, Kalpin Erlangga Silaen, and Andi Yusuf. 2021. XB-Pot: Revealing Honeypot-based Attacker's Behaviors. In *2021 9th International Conference on Information and Communication Technology (ICoICT)*. IEEE, 550–555. https://doi.org/10.1109/ICoICT52021.2021.9527422

[6] Randal Douc, Eric Moulines, Pierre Priouret, and Philippe Soulier. 2018. *Markov chains*. Springer. https://doi.org/10.1007/978-3-319-97704-1

[7] John W Essam and Michael E Fisher. 1970. Some basic definitions in graph theory. *Reviews of Modern Physics* 42, 2 (1970), 271.

[8] FBI. 2021. FBI Releases the Internet Crime Complaint Center 2020 Internet Crime Report, Including COVID-19 Scam Statistics. Retrieved May 6, 2022 from https://www.fbi.gov/news/press-releases/press-releases/fbi-releases-the-internet-crime-complaint-center-2020-internet-crime-report-including-covid-19-scam-statistics

[9] Flowmon. 2022. unknown-threat-detection. Retrieved May 6, 2022 from https://www.flowmon.com/en/solutions/security-operations/unknown-threat-detection

[10] Nikita Gandotra and Lalit Sen Sharma. 2020. Exploring the use of Iptables as an Application Layer Firewall. *Journal of The Institution of Engineers (India): Series B* 101, 6 (2020), 707–715. https://doi.org/10.1007/s40031-020-00497-y

[11] Robert J Gutierrez, Kenneth W Bauer, Bradley C Boehmke, Cade M Saie, and Trevor J Bihl. 2018. Cyber anomaly detection: Using tabulated vectors and embedded analytics for efficient data mining. *Journal of Algorithms & Computational Technology* 12, 4 (2018), 293–310. https://doi.org/10.1177/1748301818791503

[12] Filip Hock and Peter Kortiš. 2015. Commercial and open-source based Intrusion Detection System and Intrusion Prevention System (IDS/IPS) design for an IP networks. In *2015 13th International Conference on Emerging eLearning Technologies and Applications (ICETA)*. IEEE, 1–4. https://doi.org/10.1109/ICETA.2015.7558466

[13] Hossein Jadidoleslamy. 2012. Weaknesses, Vulnerabilities and Elusion Strategies Against Intrusion Detection Systems. *International Journal of Computer Science and Engineering Survey* 3, 4 (2012), 15. https://doi.org/10.5121/ijcses.2012.3402

[14] Yan-Bin Jia, Matthew T Mason, and Michael A Erdmann. 2013. Multiple impacts: A state transition diagram approach. *The International Journal of Robotics Research* 32, 1 (2013), 84–114. https://doi.org/10.1177/0278364912461539

[15] Karen Kent and Murugiah P Souppaya. 2006. SP 800-92 Guide to computer security log management. https://dl.acm.org/doi/pdf/10.5555/2206303

[16] Shiyu Li and Baojiang Cui. 2020. Research on Association Analysis Technology of Network Attack Trace Based on Web Log. In *International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing*. Springer, 33–43. https://doi.org/10.1007/978-3-030-50399-4_4

[17] K Lubna, Robin Cyiac, et al. 2013. Firewall log analysis and dynamic rule reordering in firewall policy anomaly management framework. In *2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGCE)*. IEEE, 853–856. https://doi.org/10.1109/ICGCE.2013.6823553

[18] Matthew V Mahoney. 2003. Network traffic anomaly detection based on packet bytes. In *Proceedings of the 2003 ACM symposium on Applied computing*. Association for Computing Machinery, 346–350. https://doi.org/10.1145/952532.952601

[19] N Pandeeswari and Ganesh Kumar. 2016. Anomaly detection system in cloud environment using fuzzy clustering based ANN. *Mobile Networks and Applications* 21, 3 (2016), 494–505. https://doi.org/10.1007/s11036-015-0644-x

[20] Ryandy, Charles Lim, and Kalpin Erlangga Silaen. 2020. XT-Pot: EXposing Threat Category of Honeypot-Based Attacks. In *Proceedings of the International Conference on Engineering and Information Technology for Sustainable Industry* (Tangerang, Indonesia) *(ICONETSI)*. Association for Computing Machinery, New York, NY, USA, Article 31, 6 pages. https://doi.org/10.1145/3429789.3429868

[21] Jerome H Saltzer and Michael D Schroeder. 1975. The protection of information in computer systems. *Proc. IEEE* 63, 9 (1975), 1278–1308. https://doi.org/10.1109/PROC.1975.9939

[22] Karen Scarfone and Paul Hoffman. 2009. Guidelines on Firewalls and Firewall Policy. (2009). https://doi.org/10.6028/NIST.SP.800-41r1

[23] Karen A Scarfone and Peter M Mell. 2007. SP 800-94. guide to intrusion detection and prevention systems (idps). https://dl.acm.org/doi/pdf/10.5555/2206304

[24] Robert Shirey. 2007. RFC 4949–Internet Security Glossary. *IETF2007* (2007).

[25] Joanne R Treurniet and JH Lefebvre. 2003. *A finite state machine model of TCP connections in the transport layer*. Defence R & D Canada-Ottawa.

[26] Jenna Walter. 2020. COVID-19 News: FBI Reports 300Cybercrimes. Retrieved May 6, 2022 from https://www.imcgrupo.com/covid-19-news-fbi-reports-300-increase-in-reported-cybercrimes/

Multivariate Sales Forecast Model Towards Trend Shifting During COVID-19 Pandemic

A Case Study in Global Beauty Industry

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ABSTRACT

COVID-19 pandemic has changed the economic weather and business performance in multiple streams. The uncertainty condition caused by the pandemic needs to be carefully taken care by all companies and organizations due to rapid consumer trend shifting and volatile market condition. The sales and marketing strategy needs to be carefully taken during organizational decision-making process to avoid further loss. PT XYZ as one of the leading consumer goods in beauty industry experiences the same condition and challenge reflected by down-trend in the organization KPI. This research aims to introduce and provide predictive data analytics tools for enhancing sales forecast by comparing Random Forest and Neural Network as part of machine learning methods also Vector Autoregression (VAR) as conventional statistical forecasting methodology. As the result of this research, neural network returns better evaluation for skin care and Vector Autoregression for makeup category. Meanwhile data visualization is found necessary to provide additional factual information, includes the external factor, to support knowledge management for better rational decision-making process.

CCS CONCEPTS

• **Information systems** → Information systems applications; Decision support systems; Data analytics.

KEYWORDS

COVID19, Sales Forecast, Multivariate, Machine Learning, Data analytics, Decision Making

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1 BACKGROUND

Covid-19 is considered as a critical disruptive event that cause global effect on several areas, but mainly on society and economy [1]. For retail and consumer goods industry, several studies have indicated changes on consumer and transactional behavior [2] [3] [4]. Most of the research result indicate pandemic has changed consumer behavior and decision making on the product needs [3] and way of transactions from offline to online [5]. For retail industries, the product needs shifting has a significant effect on their business. Pet and food supplies, house hold goods, and cosmetic product are the product categories with sustainable growth during pandemic meanwhile in the other hand the out of home entertainment and travel are the product categories affected negatively [6].

During market uncertainty caused by COVID-19 pandemic, PT. XYZ as one of the leading beauty industries, are currently facing a challenge on its financial key performance indicator in several categories across its product assortment, mainly in makeup category. Based on the discussions and available descriptive analytics, the challenge on financial KPI is mainly related with the consumer trend shifting which causing inaccurate organization strategy on doing marketing investment and supply chain planning. The supply chain planning plays important role on determining the stock based on sales forecast number. Sales forecast number is typically generated using simple statistical methodology by using historical sales and inventory data obtained from ERP System.

By using PT XYZ as case study, this research aims to introduce other methods on forecasting sales volume by not only utilizing internal ERP data in order to enhance sales and marketing strategy (univariate), but also utilizing external factor or exogenous variable in the forecast. This research also explains on data analytics as source in knowledge creation data-information-knowledge process [7]. In order to express the knowledge management variable, expert user tacit knowledge is also being taken into account as variable, i.e. the sales seasonality insight, as well as the special promotion upscaling (if any). Based on the pre-research investigation and interview, this study will focus on sales forecast area in the organization. Besides that, this study will complement academically current limited literature on usage of data analytics to ERP data and its role as source of knowledge management and impact to sales forecast number as organizational performance.

This research is expected to answer below questions to align with research objectives:

- What is the best forecasting model for sales forecast tools based on the evaluation measurements?

- What are parameters or features to be displayed in data visualization that can be used to interpret and reflect the sales forecast accuracy improvement compared to actual sales for organization strategy?

2 LITERATURE REVIEW

This chapter introduces basic understanding and foundation of ERP, machine learning which part of data analytics and the relationship to knowledge management and decision making, sales forecast as one of the organizational performance indicators, and also a brief explanation on COVID-19 in Jakarta Raya Area. In addition to that, high level understanding on the case study, including the enterprises and theoretical view and literature of the case study scope will also be expressed in this chapter.

2.1 Enterprise Resource Planning Data

ERP is a very important information system tool for corporation in order to manage the business processes by identify, capture, integrate, and store the flow of information as result of executing business transactions [8]. With multiple modules spans from supply chain up to finance that ERP has, ERP provides the capabilities to control information flows [9]. Based on previous studies and experience, ERP is having positive impact on its usage to the organization performance by bringing competitive advantage, it ensures cost reduction, better resource controls, improvement on decision quality, and streamlined business process [10]. In the relationship with Knowledge Management, ERP companies provide products to the client to facilitate knowledge management in whole lifecycle: Choosing ERP, Implementing ERP, and post the implementation – using and utilizing ERP [11].

2.2 Data Analytics in the Organizations

Nowadays, data is something massively available in the organization. It is then influenced many organizations in various business stream adopt data analytics and machine learning into their firm. As the result of this popular trend, data science is introduced as new discipline that discuss on how to derive insight and knowledge from the data [12]. Many organizations are interested to apply data analytics further known as big data analytics due to its positive impact to the organizations. Big data analytics is known to enhance decision making process of many businesses with recent methodology and revolutionary approach [13]. Besides improving decision making, big data analytics also improve learning and innovation in which lead to better organizational performance [14].

2.2.1 Data Analytics, Knowledge Management, and Decision Making. Big data analytics is one of the sources of knowledge creation in the organization [15]. The activity of data analytics is fundamentally about extracting information and ultimately knowledge from the raw data, this model is actually known as data-information-knowledge-wisdom model [16]. Several previous studies were exploring the relationship and map between big data analytics and knowledge management. Based on [17] big data is actually a part on knowledge management, an element to be precise. As shown in Figure 1 below, the part of 'data- information-knowledge' in data analytics is also considered as knowledge life cycle in knowledge management.

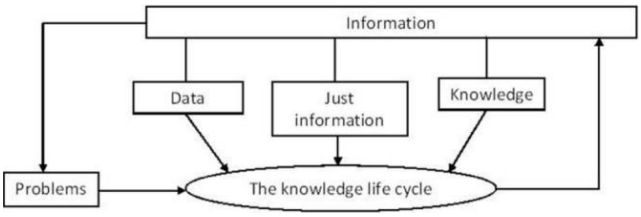


Figure 1: The Knowledge Lifecycle [17]

Wang and Wang in their research described the big data resource management is actually a form of knowledge management since big data act as major source of the explicit knowledge [18]. Another view on the relationship between big data analytics and KM is on how actually knowledge management contributes to big data analytics. The study explain that human knowledge develops the capabilities of big data analytics, by being responsible for decisions of selecting the data and analytics tools [19], [20]. Based on number of previous studies, it is indicated that big data and knowledge management are always correlated. Pauleen, in his research stated that big data can only generate big knowledge when Knowledge Management is involved [20], and enterprise can actually experience knowledge creation by using big data analytics [21].

There is a direct relationship between KM and decision-making [22]. This relationship explained as every step of decision making is influenced by knowledge management [23]. [24] in the research define two kinds of decision-making style in the organization, intuitive decision-making style and rational decision-making style. There are three elements as source of intuitive decision-making, 1) instinct or innate response, 2) general experience, and 3) focused learning [25]. In rational decision-making, comprehensive information collection is involved as well as analysis through factual information and evidence. In the organization when the rational decision-making style is involved, it is expected that business users are expected to evaluate both internal and external environment to make strategic decisions based on unbiased criteria and systematic analysis [24].

2.2.2 Predictive Data Analytics: Forecasting Methodology. Sales forecast in the organization is known as predictive analysis for future organizational strategy. This predictive analysis helps to predict future product sales by analyzing past historical data and current market data [26]. Accurate sales forecast may lead into accurate production planning in which will increase the company's revenue and also reducing cost. Prior to the trends of data analytics, many organizations or retail are using statistical- based model for univariate and multivariate time series forecast, such as linear regression, quantile regression, moving average (ARIMA, ARMA, SARIMA) [27], Vector Auto Regression, and many more [28]. But then after data analytics become popular, several machine learning techniques are introduced via many various studies [26]. Neural network techniques was applied by Kuo for forecasting [29], including recurrent neural network for sales forecast [30]. Forecasting for one of the electric companies in china are using clustering, regression,

and time series analysis techniques [31]. Advanced Machine Learning techniques are also introduced such as SVR (support vector regression) for prediction of IT Tools [32].

2.3 Sales Forecast and COVID-19

Since the first case was found in China on December 2019, the covid-19 outbreak has infected more than 346 million people globally and bring deaths to over 5 million members of the world population [33]. One of the most expected outcomes as the impact of the pandemic is the economic situation all over the world, including Indonesia. Latest research conclude that the COVID-19 outbreak will reduce of Indonesia economic growth rate by 0,8% at its best, or even reduce 8.5% at its worst scenario. The research also estimates the declining of per-capita household expenditure due to slower economic growth and fewer economic activity [34].

The declining per-capita household expenditure due to COVID-19 as mentioned previously is obviously causing disruption in number of consumers sales for certain products. In the other hand, changes of consumer behavior of buying goods are also impacting on adjustment in market sales for certain products (for example healthcare and food product sales increase significantly, furthermore due to panic buying). It is important for many organizations now to understand and face the challenges of very dynamic consumer sales pattern during the pandemic [36] to have better sales and marketing strategy in order to still achieve competitive advantage.

As the COVID-19 cases number are unpredictable, several forecast methodologies have been taken into account as predictive tools. Some of them are sales excess [36] or customer satisfaction [1] The usage of the predictive tools may vary based on the needs and the context of the information. For instance, the predictive tools on forecasting the covid-19 cases will be suitable for the related government / health official taking and firming appropriate decisions [35]. Meanwhile the predictive tools on consumer sales might be beneficial for organization on deciding supply chain and commercial strategy in order to gain competitive advantage.

2.3.1 Multivariate Forecasting Methodology. There are several forecasting methodologies that consider several variables to build forecast number, known as multivariate forecast method. In multivariate forecasting methodology, the prediction model will be built not only based on endogenous variable but also exogenous variables. One of the popular multivariate time series forecasting is Vector Autoregression (VAR). VAR is a multivariate time series statistical model that consider multiple variables are dependent for building a prediction model of one target variable. In VAR, each variable uses its own past value and other variable past values in the system [37]. VAR model with k variables and p lags can be expressed mathematically as

$$Y_t = B_0 + BY_{t-1} + BY_{t-2} + \ldots + B_p Y_{t-p} + \in_t \quad (1)$$

Vector Autoregression is a well-known statistical time series modelling for generating forecast number. But however, VAR has a pre-requisite of non-seasonality data, this means the variables being forecasted must be stationary, which can be tested using Augmented Dickey Fuller Test (ADF). A time series is considered stationary if its mean and standard deviation are stable and steady over the time. If a time series is stationary then it has a larger possibility in repeating the behavior in the future, hence, will be easier to forecast. The most famous method for achieving stationary of time series is transforming the dataset by doing differencing. Besides statistical-based multivariate forecast, machine learning based (supervised learning) forecast is also being used to predict future value of target variable by using numbers of other variables (multivariate). One of the most popular machine learning methods is Artificial Neural Network (ANN). ANN is widely being used for sales forecast because of its flexible behavior on detecting data pattern [38].

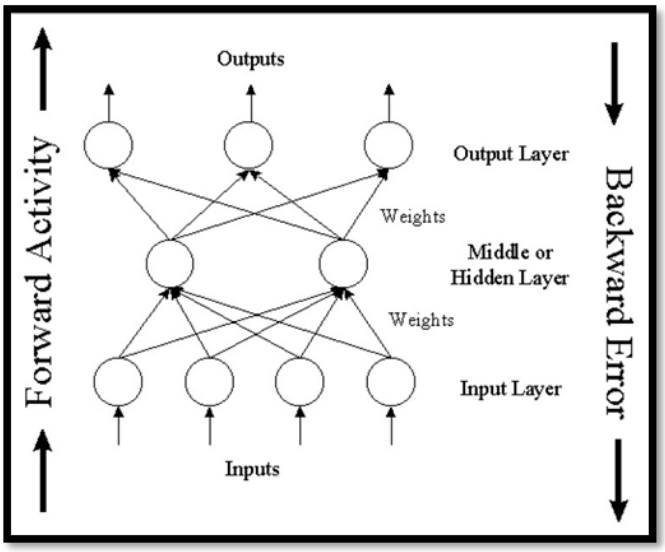


Figure 2: Neural Network Model [39]

As discussed previously ANN can learn from the multi-variable data and identify the pattern and predict future value. ANN model can be written mathematically as follow:

$$y_t = \alpha_0 + \sum_{j=1}^{n} \alpha_j f\left(\sum_{i=1}^{m} \beta_{ij} y_{t-i} + \beta_{0j}\right) + \varepsilon_t \quad (2)$$

With number of nodes in the input layer are denoted by m and in hidden layers. Figure 2 illustrate standard neural network model.

Other machine learning method that is known works for multivariate forecasting is random forest. Random Forest is a tree-based models and use splitting in order to build a model based on ensemble of univariate tree [40]. Even though random forest is a tree-based classifier, since it is ensemble of tree, the number of splits and calculation of impurity and happening across variables. The variables used to build each tree are also randomly selected from the total set of input variables available. [41]. The dataset is first split into two sets of data, train data and test data, there are several methods on doing this, but the simplest one is known as common split [27], [42] in which splitting the train and test data by percentage (75% and 25%, 80 and 20%, etc). The model then be tested by test set by using several evaluation criteria in which will be discussed in next section.

2.3.2 Forecast Model Evaluation. There are several measurements being used for evaluating forecast model. But the most common and popular for time series forecast is MSE, RMSE, and MAPE. These measurements is also being used and discussed in some research related to forecast [27], [43]. Mean Square Error is defined as the variance between predicted and actual values (average). The lower MSE values the better model is. If the MSE value is 0.00, it means no error value occurs in the prediction model.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(P_i - A_i)^2 \tag{3}$$

Where n is the number of samples, P is the predicted value and A is the actual value. Root-Mean Square Error represents the error-index, which is used to compare different forecasting models. This is the square root of the square differences measured between prediction and actual observation.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - A_i)^2} \tag{4}$$

Where n is the number of samples, P is the predicted value and A is the actual value. MAPE (Mean Absolute Percentage Error) is one of the popular and preferred evaluation criteria of sales forecast. The opposite of MAPE, is widely known as forecast accuracy.

$$MAPE = \frac{100\%}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \tag{5}$$

where At is the actual value and Ft is the forecast value.

3 EXPLORATORY DATA ANALYSIS

Prior to build the forecasting tools, understanding each data and features is performed through exploratory data analysis. The transformed data set contains 288 data points from originally 1288 data points. In the initial data we have 11 features represented as data column, they are row labels, positivity percentage, EUR to IDR, SKIN STOCK, SKIN SI, MAKE SI, MAKE STOCK, SKIN ACTUAL SO, MAKE ACTUAL SO, SOCIAL, SPECIAL, and FESTIVE. The data analysis is initiated by plotting the target variables in which the sales out data for both skin care and makeup product category to have better visualization of the target variable. Prior to the plotting, to have better insight on trend shifting between category, the data is normalized to its mean and standard deviation. The COVID-19 positivity rate is also plotted as important exogenous variable to have better descriptive analysis between variables.

As depicted in Figure 3, there is a unique relationship that can be identified visually by looking into the plotted data between monthly average of positivity rate and sales out data. When the covid-19 positivity rate is increasing, majority the sales out for both skincare and makeup category are decreasing. It explains that covid-19 positivity rate is having negative relationship with product sales, obviously in real world, more people will stay at home during high case of COVID-19 pandemic and do less shopping through outlet store. This line plot is also showing that during the first year of COVID-19, skincare product sales recover faster than makeup product. This is reflecting also during 1st year of COVID-19 less people buying makeup product and shifting to skin care product. But after a year, during 2nd year we can see that makeup category

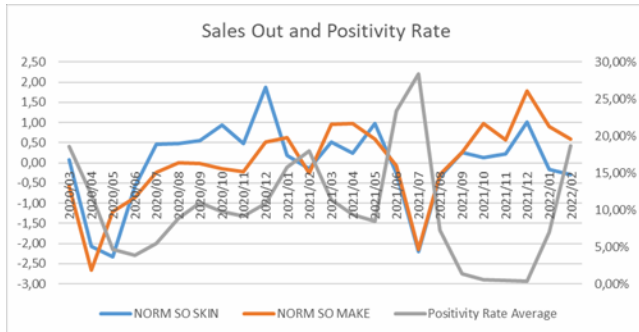
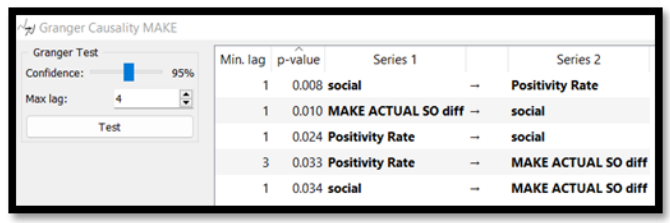
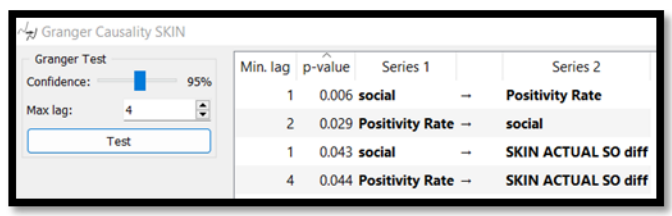


Figure 3: Sales Out and COVID-19 Positivity Rate Data Visualization



Min. lag	p-value	Series 1		Series 2
1	0.008	social	→	Positivity Rate
1	0.010	MAKE ACTUAL SO diff	→	social
1	0.024	Positivity Rate	→	social
3	0.033	Positivity Rate	→	MAKE ACTUAL SO diff
1	0.034	social	→	MAKE ACTUAL SO diff

Figure 4: Granger Causality Test for Makeup Category



Min. lag	p-value	Series 1		Series 2
1	0.006	social	→	Positivity Rate
2	0.029	Positivity Rate	→	social
1	0.043	social	→	SKIN ACTUAL SO diff
4	0.044	Positivity Rate	→	SKIN ACTUAL SO diff

Figure 5: Granger Causality Test for Skincare Category

recover faster than skincare, ultimately with increasing trend since September 2021 onwards. It is clear that as organization, this trend shifting must be addressed with correct and accurate sales and marketing strategy

4 BUILD FORECAST MODEL

4.1 Causality and Stationary Test

One of the forecasting methodologies being used in this research is Vector Autoregression (VAR). Prior to have forecast model by using VAR method, the causality test is being carried out to determine features that will be nominated as key features that will have causality to the target variables. In this research, Granger Causality Test is being performed to determine variables that will be used during forecast modelling using VAR Model.

By looking into Granger Causality test result as showed by Figure 4 and Figure 5 the chosen variables those will be used for build forecast model for skincare are social, positivity rate, and SKIN ACTUAL SO, and for makeup are social, positivity rate, and MAKE

Table 1: Skincare Evaluation Result based on Multiple Forecast Methodologies

SKINCARE	MSE	RMSE	MAPE
Vector Autoregression	3361043	1833,31	38,57%
Random Forest	266434,2	516,17	8,31%
Neural Network	515820,2	654,99	13,74%

Stationary Test SKIN SO DIFF					
Test	Score	P-	C,V,	Stationary?	5,0%
ADF					
No Const	-5,8	0,1000%	-2,1	TRUE	
Const-Only	-5,7	0,2453%	-3,4	TRUE	
Const + Trend	-5,7	0,0000%	-1,6	TRUE	
Const+Trend+Trend^2	-5,5	0,0000%	-1,6	TRUE	
Stationary Test MAKE SO DIFF					
Test	Score	P-	C,V,	Stationary?	5,0%
ADF					
No Const	-6,9	0,1%	-2,1	TRUE	
Const-Only	-6,9	0,1%	-3,4	TRUE	
Const + Trend	-6,9	0,0%	-1,6	TRUE	
Const+Trend+Trend^2	-6,7	0,0%	-1,6	TRUE	

Figure 6: ADF Test for Sales Out Difference Data

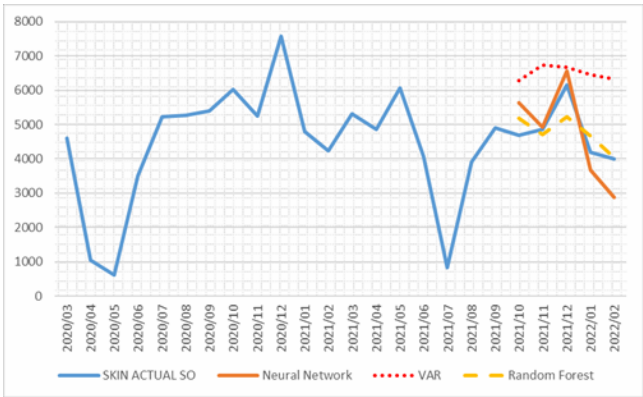


Figure 7: Forecast Result Illustration for Skincare Product Category

ACTUAL SO. After nominating the features, it is also important for variables in which will be included in the modelling to be stationary to ensure removal of significant seasonality and trend. The calculation shows the stationary test by using Augmented Dickey Fuller Test using NumXL Software is returning non-stationarity for sales out data, for these sales out data, the transformation is needed in order to achieve the stationary, hence, we use differencing and run the stationary again and resulted stationary as shown in Figure 6.

4.2 Time Series to Supervised Learning Data Transformation

In machine learning forecast modelling, the time series data needs to be transformed to supervised learning problem, in which will have input variable and target variable. This can be done by using previous observed data as an input. In this case, the sales out from previous three months are being used as input variable (M-1, M-2, and M-3), as well as the sell in value (M-1, M-2, and M-3). Average monthly sales for the past three months are also being used as input variable. In total, there are 26 variables being used in this supervised learning problem, but for each category, there are 16 variables being used for skincare and 16 used for makeup (with 6 sharing variables).

4.3 VAR, Random Forest, and Neural Network

During forecast modelling using Vector Autoregression method, 19 point of time series is being used as training data to build the forecast, and remaining 5 point of time series is being a test data. Later, in the calculation of evaluation forecast model will compare forecast result. Random Forest is being used as one of the methodologies on forecast modelling. The parameter set for random forest is 100 number of trees and since number of variables being used is 15 variables, the number of attributes being considered in each split is $\sqrt{15}$ which is approximately 4 attributes in each split. Neural Network is also being used as one of supervised learning method in this research. After several simulation run using Orange Data Mining Software, the parameter used in neural network is only one layer used with 1000 neuron and ReLu activation function.

5 RESULT AND DISCUSSIONS

The data visualization for above forecast method can be seen in Figure 7 and Figure 8. The best method can be explained visually by this graph. The graph display vary result between model but all model looks can explain the inclination on near to end of 2021 and declining sales in the beginning of 2022.

Evaluation of the model is carried out to determine best model for each product category by using certain error measurement and visualization. Table 1 and Table 2 shows the error calculation in this research. Error parameters being used in this research are common KPIs for determining forecast performance, which are Mean Square Error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE).

For skincare, machine learning provides more promising result compared to time series forecast with regards to performance. The random forest returned lowest RMSE and lowest MAPE, in this case giving us better forecast accuracy for 5 months observation. In the other hand, the neural network returned moderate number of error measurement but from the visualization we can see that the neural network can explain the seasonality very well since it is having closest line pattern compared to the actual sales.

Table 2: Makeup Evaluation Result based on Multiple Forecast Methodologies

MAKEUP	MSE	RMSE	MAPE
Vector Autoregression	10570	102,81	8,67%
Random Forest	59891	244,73	32,91%
Neural Network	59780	270,03	19,08%

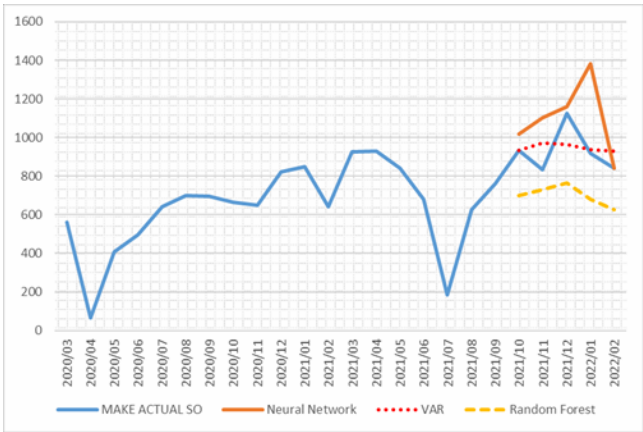


Figure 8: Forecast Result Illustration for Makeup Product Category

For makeup, the time series forecast perform better compared to machine learning based on error measurement. VAR returned lowest number of RMSE and MAPE. From the visualization, VAR-based forecast model looks flat and not really explaining the seasonality slope well in the other hand random forest and neural network are also not showing satisfactory result and not explaining the seasonality well.

6 CONCLUSIONS

From the forecast model generated previously, data visualization is considerably important. From the result of error measurement and data visualization provided in previous section, both analysis of error rate and data visualization are equally important than single analysis. The smallest error rate doesn't imply on how close the seasonality and pattern plotted in the visualization. As an example, on skincare forecast result, if only considering error measurement, random forest might be nominated as best method, but when evaluation is being done through visualization on plotted data, the neural network performs better than random forest by reflecting better and closer trend line compare to the actual numbers.

The data visualization may give important information to the expert user on decision making process other than error measurement. In order to provide better data-information-knowledge to the business user as the result of this research, then below parameter are being considered as part of data visualization that may contribute to expert user knowledge creation for better sales and marketing strategy:

- Plot of actual historical sales out actual data (year to date).
- Plot of sales out forecast data (YTD) and 12 months forecast period (future).
- Error measurement (MAPE) & Forecast Accuracy (100%-MAPE).
- Exogenous variable – COVID-19 positivity rate, Social Restriction Level.

This research contributes to the organization by providing first ever multivariate forecasting methodology to the business planner by including COVID-19 data into forecast model creation as well as providing normalized data visualization across category. The provided data visualization may complement current sales forecast quarter review as additional knowledge in the consensus meeting. By providing additional information on how external data (known as exogenous variable) as well as modelled tacit knowledge may give new perspective on sales forecast determination. In the other hand, for machine learning based forecast model, since COVID-19 positivity rate considered as input (independent variable), expert user might be able to adjust COVID-19 data as self-input data to investigate the sales out forecast number. This will provide additional information to the expert user that would be beneficial for rational decision making on top of intuition-based decision making in which common in forecast generation.

REFERENCES

[1] P. Brandtner, F. Darbanian, T. Falatouri, and C. Udokwu, "Impact of COVID-19 on the Customer End of Retail Supply Chains: A Big Data Analysis of Consumer Satisfaction," Sustainability, vol. 13, no. 3, 2021, doi: 10.3390/su13031464.
[2] T. F. Rukuni and E. T. Maziriri, "Data on corona-virus readiness strategies influencing customer satisfaction and customer behavioural intentions in South African retail stores," Data Br., vol. 31, p. 105818, 2020, doi: https://doi.org/10.1016/j.dib.2020.105818.
[3] A. Mason, J. Narcum, and K. Mason, "Changes in consumer decision- making resulting from the COVID-19 pandemic," J. Cust. Behav., vol. 19, no. 4, pp. 299–321, 2020.
[4] B. Sharma, "DON'T MISS THE FOREST FOR THE TREES: MANAGING CUSTOMER SATISFACTION, TRUST AND LOYALTY IN RETAILING DURING COVID-19.," 2020, pp. 29–40.
[5] P. Dannenberg, M. Fuchs, T. Riedler, and C. Wiedemann, "Digital Transition by COVID-19 Pandemic? The German Food Online Retail," J. Econ. Hum. Geogr., vol. 111, no. 3, pp. 543–560, 2020.
[6] McKinsey & Company, "US consumer sentiment and behaviors during the coronavirus crisis," McKinsey & company, 2021.
[7] M. Alavi and D. E. Leidner, "Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues," MIS Q. Manag. Inf. Syst., vol. 25, no. 1, pp. 107–136, 2001, doi: 10.2307/3250961.
[8] M. F. Acar, M. Tarim, H. Zaim, S. Zaim, and D. Delen, "Knowledge management and ERP: Complementary or contradictory?," Int. J. Inf. Manage., vol. 37, no. 6, pp. 703–712, 2017, doi: 10.1016/j.ijinfomgt.2017.05.007.
[9] M. M. Migdadi and M. K. S. Abu Zaid, "An empirical investigation of knowledge management competence for enterprise resource planning systems success: insights from Jordan," Int. J. Prod. Res., vol. 54, no. 18, pp. 5480–5498, 2016, doi: 10.1080/00207543.2016.1161254.
[10] S. Newell, J. C. Huang, R. D. Galliers, and S. L. Pan, "Implementing enterprise resource planning and knowledge management systems in tandem: Fostering efficiency and innovation complementarity," Inf. Organ., vol. 13, no. 1, pp. 25–52, 2003, doi: 10.1016/S1471-7727(02)00007-6.

[11] D. E. O'Leary, "Knowledge management across the enterprise resource planning systems life cycle," Int. J. Account. Inf. Syst., vol. 3, no. 2, pp. 99–110, 2002, doi: 10.1016/S1467-0895(02)00038-6.

[12] S. J. Qin and L. H. Chiang, "Advances and opportunities in machine learning for process data analytics," Comput. Chem. Eng., vol. 126, pp. 465–473, 2019, doi: 10.1016/j.compchemeng.2019.04.003.

[13] J. Hagel, "Bringing Analytics to Life," J. Account., vol. 219, no. 2, pp. 24–25, 2015, [Online]. Available: http://sfx.scholarsportal.info/ottawa?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&genre=article&sid=ProQ:ProQ%253Aabiglobal&atitle=Bringing+Analytics+to+Life&title=Journal+of+Accountancy&issn=00218448&date=2015-02-01&volume=219&issue=2&sp.

[14] C. Yiu, The Big Data Opportunity Making government faster, smarter and more personal. London: Policy Exchange, 2012.

[15] S. Lavalle, E. Lesser, R. Shockley, M. S. Hopkins, and N. Kruschwitz, "Big Data , Analytics and the Path From Insights to Value Big Data , Analytics and the Path From Insights to Value," MIT Sloan Manag. Rev., vol. 52, no. 52205, pp. 21–31, 2011.

[16] A. Targowski, "From Data to Wisdom," Dialogue and Universalism, vol. 15, no. 5, pp. 55–71, 2005, doi: 10.5840/du2005155/629.

[17] X. Tian, "Big data and knowledge management: a case of déjà vu or back to the future?," J. Knowl. Manag., vol. 21, no. 1, pp. 113–131, 2017, doi: 10.1108/JKM-07-2015-0277.

[18] S. Wang and H. Wang, "Big data for small and medium-sized enterprises (SME): a knowledge management model," J. Knowl. Manag., vol. 24, no. 4, pp. 881–897, 2020, doi: 10.1108/JKM-02-2020-0081.

[19] C. M. Olszak and E. Ziemba, "Critical success factors for implementing business intelligence systems in small and medium enterprises on the example of upper Silesia, Poland," Interdiscip. J. Information, Knowledge, Manag., vol. 7, pp. 129–150, 2012, doi: 10.28945/1584.

[20] D. J. Pauleen, "Davenport and Prusak on KM and big data/analytics: interview with David J. Pauleen," J. Knowl. Manag., vol. 21, no. 1, pp. 7–11, 2017, doi: 10.1108/JKM-08-2016-0329.

[21] M. Chen, S. Mao, and Y. Liu, "Big data: a survey," Mob. Netw Appl, vol. 19, no. 2, pp. 171–209, 2014.

[22] D. J. Skyrme, "The 3Cs of Knowledge Sharing: Culture, Co-operation and Commitment," Updat. Int. News, vol. 13, pp. 1–4, 2002, [Online]. Available: http://www.skyrme.com/updates/u64_f1.htm.

[23] N. Rolland, "Knowledge management impacts on decision making process," J. Knowl. Manag., vol. 8, pp. 20–31, 2004, doi: 10.1108/13673270410523880.

[24] A. M. Abubakar, H. Elrehail, M. A. Alatailat, and A. Elçi, "Knowledge management, decision-making style and organizational performance," J. Innov. Knowl., vol. 4, no. 2, pp. 104–114, 2019, doi: 10.1016/j.jik.2017.07.003.

[25] J. R. Patton, "Intuition in decisions," Manag. Decis., vol. 41, no. 10, pp. 989–996, 2003.

[26] M. A. Khan *et al.*, Effective Demand Forecasting Model Using Business Intelligence Empowered with Machine Learning, vol. 8. IEEE Access, 2020.

[27] Y. Ensafi, S. H. Amin, G. Zhang, and B. Shah, "Time-series forecasting of seasonal items sales using machine learning – A comparative analysis," Int. J. Inf. Manag. Data Insights, vol. 2, no. 1, p. 100058, 2022, doi: https://doi.org/10.1016/j.jjimei.2022.100058.

[28] N. S. Arunraj and D. Ahrens, "A hybrid seasonal autoregressive integrated moving average and quantile regression for daily food sales forecasting," Int. J. Prod. Econ., vol. 170, pp. 321–335, 2015, doi: 10.1016/j.ijpe.2015.09.039.

[29] R. J. Kuo, "Sales forecasting system based on fuzzy neural network with initial weights generated by genetic algorithm," Eur. J. Oper. Res., vol. 129, no. 3, pp. 496–517, 2001, doi: 10.1016/S0377-2217(99)00463-4.

[30] M. Müller-Navarra, S. Lessmann, and S. Voß, "Sales forecasting with partial recurrent neural networks: Empirical insights and benchmarking results," in Proceedings of the Annual Hawaii International Conference on System Sciences, 2015, vol. 2015-March, pp. 1108–1116, doi: 10.1109/HICSS.2015.135.

[31] J. Zhao *et al.*, "A novel electricity sales forecasting method based on clustering, regression and time-series analysis," in Proceedings of Science, 2015, vol. 12-13-Sept, doi: 10.22323/1.259.0015.

[32] C. J. Lu, T. S. Lee, and C. M. Lian, "Sales forecasting of IT products using a hybrid MARS and SVR model," in Proceedings - IEEE International Conference on Data Mining, ICDM, 2010, pp. 593–599, doi: 10.1109/ICDMW.2010.11.

[33] WHO, "COVID-19 Weekly Epidemiological Update," Geneva, 2022. [Online]. Available: https://www.who.int/publications/m/item/weekly- epidemiological-update-on-covid-19—25-january-2022.

[34] A. Suryahadi, R. Al Izzati, and D. Suryadarma, "Estimating the Impact of Covid-19 on Poverty in Indonesia," Bull. Indones. Econ. Stud., vol. 56, no. 2, pp. 175–192, 2020, doi: 10.1080/00074918.2020.1779390.

[35] S. Namasudra, S. Dhamodharavadhani, and R. Rathipriya, Nonlinear Neural Network Based Forecasting Model for Predicting COVID-19 Cases. Neural Processing Letters, 2021.

[36] K. Nikolopoulos, S. Punia, A. Schäfers, C. Tsinopoulos, and C. Vasilakis, "Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions.," Eur. J. Oper. Res., vol. 290, no. 1, pp. 99–115, Apr. 2021, doi: 10.1016/j.ejor.2020.08.001.

[37] K. Holden, "Vector Autoregression modelling and forecasting," J. Forecast., vol. 14, no. 3, pp. 159–166, 1995.

[38] M. Tkáč and R. Verner, "Artificial neural networks in business: Two decades of research," Appl. Soft Comput., vol. 38, pp. 788–804, 2016, doi: https://doi.org/10.1016/j.asoc.2015.09.040.

[39] O. Abbas, "Neural Networks in Business Forecasting," Int. J. Comput., 2005.

[40] C. Behrens, C. Pierdzioch, and M. Risse, "A test of the joint efficiency of macroeconomic forecasts using multivariate random forests," J. Forecast., vol. 37, 2017, doi: 10.1002/for.252

[41] C. González, J. Mira, and J. Ojeda, "Applying Multi-Output Random Forest Models to Electricity Price Forecast," Preprints, 2016, doi: 10.20944/preprints201609.0053.v1.

[42] E. Avuçlu and A. Elen, "Evaluation of train and test performance of machine learning algorithms and Parkinson diagnosis with statistical measurements," Med. Biol. Eng. Comput., vol. 58, no. 11, pp. 2775–2788, 2020, doi: 10.1007/s11517-020-02260-3.

[43] C. Hamzaçebi, "Improving artificial neural networks' performance in seasonal time series forecasting," Inf. Sci., vol. 178, pp. 4550–4559, 2008, doi: 10.1016/j.ins.2008.07.

Malware Classification Method Using API Call Categorization

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ABSTRACT

The development of malware and computer security countermeasures is in a continuous arms race. Malware authors will adapt their malware according to the current state of events to maximize their chance of success. This increases the value of rapidly detecting the presence of malware within a system and identifying the type of malware. This research proposes a new method of classifying malware using API call categorization based on markov chain. The proposed methods have demonstrated a moderate accuracy of 87.19% with an f-1 score of 75.18%.

CCS CONCEPTS

• **Security and privacy** → *Malware and its mitigation.*

KEYWORDS

Markov Chain analysis, Graph based analysis, Malware analysis

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1 INTRODUCTION

Security threats, are always changing to adapt to the current situation within the world which also drive advancements in cyber security. AV-TEST regularly releases statistical information and graphs relating to the malware trends [2]. The reports show that new malware samples are continuously being discovered. The attackers through malware and other security attacks adapt to the current situation in order to be more effective. Pacag [14] released an article on TrustWave that shows an example of a phishing attack that makes use of the covid-19 situation to encourage the targets to click on malicious links. These attacks make use of the situation to trick the targets to open attachments or click on links that they usually would avoid. MalwareBytes Labs [9] released a report that shows malware trends for 2021. The overall number of detected malware have decreased however there is a significant increase in HackTool and Rogue malware detection. Malwarebytes also mentioned in their report the appearance of Egregor, a new ransomware family that primarily targets large companies.

Malware behavior ranges from identifying saved credentials within the infected system and transferring them to the attacker encrypting all the data of an infected system and demanding ransom. Therefore malware is commonly categorized into families based on purpose and their behavior, which helps analysts to device necessary preventive and responsive measures. Malware analysis processes are used to identify its behavior and its capability.

The development of new more sophisticated malware is ongoing and is on an ongoing race with computer security and its countermeasures. Malware authors use various methods to prevent detection and analysis. One such method, a packer is often used to compress and encrypt the malware. This method of obfuscation prevents malware from being detected using signature-based malware detection. With the advancement of malware, the ability to quickly detect it within a system and then to identify its behavior is important in keeping a system or network secure. Unfortunately, significant time and resources are required for accurate categorization, the problem addressed in this research. The aim is to develop a method capable of identifying malware and categorized them into both known and unknown families, and in addition to provide possible insights to the behavior of that malware.

Following are the contributions of this research:

- An API call categorization system have been developed by using MITRE ATT&CK data sources and data components as a basis for the categories. Regular expressions are matched to API call names to categorize the API calls. Using this categorization system malware classification are able to be performed using this categorization system.
- A malware classification method with an accuracy of 87.19% . Converting an API call sequence obtained from dynamic analysis and producing an API call category sequence, then using the API call category sequence to construct API call category transition probability graphs to identify and classify malware by using a similarity score and threshold values obtained.

The structure of the remainder of this paper is organized in the following order: Section 2 describes related concepts and previous works that are related to this research. Section 3 explains the framework of this research. Section 4 shows the result of the performed experiments. Section 5 shows the analysis of the experiment results. Section 6 concludes the findings of this research.

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2 BACKGROUND

2.1 MITRE ATT&CK

MITRE ATT&CK Mitre [12] is a knowledge base of strategies and techniques used by cyber security attackers that is based on observations of real-world attacks. This knowledge base contains strategies used and the techniques used within that strategy that have been observed in real-world attack scenarios. A part of this attack categorization within the MITRE ATT&CK knowledge base is data sources. MITRE ATT&CK Data sources Mitre [11] are topics of data that are able to be collected by sensors within a system. The topics cover what kinds of operations are being performed on the type of data operated. Each data source topic is divided into data components that detail more specifically what operations can be performed on the data source. The data sources and data components will be used as a base for the classification process because it will be able to provide a set of categories that encapsulates different behaviors.

2.2 Markov Chain

A markov chain is a model that shows all the possible states or events that is able to be transitioned into given a current known state or event. This model is the basis of the API call category transition probability graph. Markov chains only use the current state as an indication of what the next transitioned state will be. The markov chain is often used to represent real-world occurrences in a statistical model. Markov chains are often represented in the form of a transition matrix where the value in the matrix is the probability of one state transitioning into a different one. This graph will be the type used for this research. The markov chain is able to represent the whole sequence without traversing the full sequence of each sample outside of the construction phase. This will reduce the total resources and time consumed for the classification process

2.3 Related Works

Dynamic analysis of malware often use the sequence of API calls or system calls performed by the malware to identify malware from benign samples and to classify malware samples to their classifying families. Ki et al. [8] uses the API call sequence generated that has undergone sequence alignment using DNA sequence alignment algorithms to detect malware samples from benign samples. The result is a 99% accuracy score but the drawback of using DNA sequence alignment is a large amount of time and resources are required. Gupta et al. [5] designed a method of classification by generating fuzzy hashes and using them to perform malware classification. The generated fuzzy hashes are then compared to the fuzzy has database using matching algorithms to determine the similarity of samples to a particular family. Malware classification using this method reaches an accuracy of 96.33%. These methods have reached high accuracy results however one of the drawbacks are the lack of behavior data that can be obtained from the sequences themselves. Table 1 list relevant research that haa been previously done.

Graph based analysis aims to help reduce this drawback. The flexibility of graphs allow different relationships between the datasets to be modeled within the graphs.D'Angelo et al. D'Angelo et al. [4] developed a method that uses the transition probability of 2 API calls that are not necessarily contiguous. This information is modeled using a markov chain to denote the probability of one API call occurring given the previous API call. This method was able to achieve an accuracy of 99% and an f measure of 96%. Suaboot et al. Suaboot et al. [17] uses the API call sequences to train a hidden markov model to perform malware detection. They used an approach that uses subsets of API call sequences in place of the sequence as a whole with the goal of being able to perform malware detection with shorter API call sequences. This method has a detection accuracy of 94%

Table 1: Related Works

Research	Analysis Method
Anderson et al. [1]	Markov Chain
Martín et al. [10]	Markov chain with states of system trace categories
Onwuzurike et al. [13]	Markov chain of abstracted API calls
Han et al. [6]	API call sequence feature vector
Han et al. [7]	API call sequence feature vector
Chen et al. [3]	API call flow graph feature vector
Park et al. [15]	Kernel object behaviour graph
Wüchner et al. [18]	quantitative data flow graphs
Proposed method	API Call category transition probability graphs

3 RESEARCH FRAMEWORK

3.1 Process Architecture

There are 3 key processes: markov chain construction, malware classification, and result validation.

3.1.1 Markov Chain Construction. The following processes are performed during the markov chain construction process. This process takes in malware samples and input and outputs the API call category transition probability matrix.

(1) Malware samples are processed using the Cuckoo sandbox dynamic analysis tool that produces a report that contains the API call sequence.
(2) The API call sequence is extracted from the dynamic analysis report.
(3) The extracted API calls are then categorized based on their operations and a sequence of API call categories is created.
(4) The API call category sequence is then transformed into a transition matrix that denotes all the transitions that is within the sequence of categories that is then used to construct the markov chain that contains the category transition probability.

3.1.2 Malware Classification. The malware classification process uses the constructed markov chain to determine if the sample is benign or belongs to a malware family. The similarity between the sample and family API call category transition probability graph is calculated, then the threshold values are calculated in order to calculate the confidence level.

3.1.3 Result Validation. The result validation process takes in the classification results and validates the result. First the classification

result is counted based on the correctness of the result. The resulting values are used to calculate the f-score and accuracy of the proposed method.

3.2 API Call categorization

The categorization of API calls uses the MITRE ATT&CK data sources and data components Mitre [11] that are shown within table as a basis for the API call categories. The MITRE ATT&CK data sources are topics that are collected from logs and sensors or logs. The data sources include data components that provide additional properties of the data source. The API call sequence is converted into an API call category sequence using regular expression matching. The exact name of the API call is not used in the matching process to reduce the amount of comparisons needed to be made. Multiple API calls that belong in the same category contain the same sub-string pattern. Previous work by [6] uses the regular expression matching method for API call categorization. Table 2 shows the an example of the category and regular expression used in the categorization process.

Table 2: Setfile category and the regular expression matching used in [6]

Category	Regular Expression
Setfile	*CreateFile*, *ReadFile*, *WriteFile*, *OpenFile*, *Get * File*, *CopyFile*, *Find * File*, *DeleteFile*, *Get * Path*, *SearchPath*, *CreateDirectory*, *Get * Directory*, *OpenDirectory*, *Set * File*, *Get * Folder*, *MoveFile*, *Query * File, *DeleteFile*, *RemoveDirectory*, *NtdeviceIOControlFile*

3.3 Markov Chain Generation

Cuckoo sandbox generates a report of an analyzed malware sample that contains the API call sequence performed by the malware sample. The markov chain is generated in matrix form to in order to simplify the automated processing of the API call category sequence. The matrix form of the markov chain denotes all the transition probabilities of all the nodes within the graph. The API call category sequence is converted into an adjacency matrix that contains the frequency of transitions between the API call categories. This frequency matrix is used to calculate the transition probability matrix of each category. The following is the steps required to generate the markov chain:

(1) Perform dynamic analysis on malware sample using cuckoo sandbox.
(2) Extract API call sequence from the report generated by cuckoo sandbox.
(3) API calls sequence is converted to API Call category sequence.
(4) Generate API call category transition frequency matrix.
(5) Generate API call category transition probability matrix from the transition frequency matrix.

3.4 Malware Classification Evaluation

The classification will use a similarity score between 2 markov chains. Equation 1 shows the method of calculating the similarity score, as proposed by [16]:

$$score(A,B) = \frac{1}{N^2}(\sum_{i,j=0}^{N-1} |a_{ij} - b_{ij}|)^2 \tag{1}$$

Where:

$$A, B = 2differentmarkovchain$$

$$N = Totalnumberofcategories$$

$$a_{ij} = probabilityofcategoryfromcategoryitojinmarkovchainA$$

$$b_{ij} = probabilityofcategoryfromcategoryitojinmarkovchainB$$

Once the similarity scores have been obtained 2 threshold values are calculated for each API call category transition probability graph. The similarity scores between samples that are used to calculate the API call category transition probability graph and the graph itself is used to calculate the upper threshold and the similarity scores between the samples belonging to a different family from the graph are used to calculate the lower threshold. The average value of the similarity score sets will be the threshold value. The upper threshold represent the upper limit of similarity scores if the family of the sample and the graph is the same and the lower threshold is the expected values if the family is confirmed to be different. Following are the steps to obtain the upper and lower threshold:

(1) Generate markov chain for a collection malware samples
(2) Generate markov chain for a collection of benign samples
(3) Using equation 1 calculate the similarity score for a set of samples within the same family
(4) Using equation 1 calculate the similarity score for a set of samples of a different family
(5) The upper threshold is the average of the score from step 3
(6) The lower threshold is the average of the score from step 4

The following equation 2 calculates the confidence level of the classification process using the similarity scores and thresholds calculated:

$$Confidence = \frac{s - LT}{UT - LT} \tag{2}$$

Where

$$UT = Upperthreshold$$

$$LT = LowerThreshold$$

$$s = similarityscore$$

obtained from 1

4 EXPERIMENT RESULT

4.1 Hardware Setup

Table 3 lists the hardware specifications of both the host Ubuntu desktop and the client windows virtual machine.

Table 3: Hardware Setup

Hardware	Specification	Description
Desktop	Intel Core i7-4790 CPU 3.60GHz,16GB RAM, 2TB HDD,Ubuntu 18.0.4 Operating system	Main device used to perform analysis.
Virtual Machine	1 Processor with 1 core, 2GB RAM, 32GB HDD, Windows 7x36 Operating system	Client virtual machine for the dynamic analysis environment

4.2 Software Setup

Table 4 shows the software specifications used in this research. Ubuntu 18.04 is the OS of the host device and Virtualbox is used to run virtual machines within the host device. Cuckoo sandbox is installed in the host machine to perform dynamic analysis of the malware samples that are executed in the client windows virtual machine. Additional software are installed within the windows virtual machine to simulate a user machine. The experiment and analysis of the dataset are automated with the use of Python and Bash scripts.

Table 4: Software Setup

Software	Specification	Description
Virtual Machine	Oracle VM VirtualBox 4.2.0	Virtual machine engine for Windows client
Dynamic Analysis Tool	Cuckoo Sandbox 2.0.7	Dynamic analysis tools to trace the API call sequences.
Scripting Tools	Python 3.5, GNU Bash 5.0	Scripting tools to assist in analysis automation

4.3 Malware Dataset

Table 5 shows all the malware families that will be used. 40 samples of each malware family is collected for a total of 640 samples. 30 samples will be used to construct the markov chain and 10 samples will be used to test the classification method.

Table 5: Malware Family Dataset

Malware Families		
Coin Miner	GandCrab	Zeus
NjRAT	Agent Tesla	BlackShade
Gh0st	Tinba	Zeus
AveMariaRAT	Quakbot	AZORult
Redline	XMRig	Dridex
Ramnit	NanoCore	SmokeLoader

4.4 API Call Category Markov Chain

API calls that do not fit exactly to the MITRE ATT&CK data sources and data component definitions are discovered. It is difficult to determine the purpose of the API call without additional information, such as input and output of the API call. There are also API calls that do not fit into a MITRE ATT&CK data source. New categories are created based on the data the API call operates on. Table 6 contains the list of all categories that will be used in the categorization process. Additional categories, “Start_Point” and “End_Point”, are added to indicate the start and termination of the sequence. The categories are used to create the API Call Category Markov Chain using the process explained in 3.3. Figure 1 shows a graphical representation of the markov chain that is constructed. The nodes of the graph represent all the categories of all the API calls that are found in the dynamic analysis reports and the edges represent the transition probability from one category to another, where probability values of the edges determine the thickness of the edges.

Table 6: API Call Category List

Categories	
File Create	Registry Create
File Modify	Registry Access
File Access	Registry Modify
File Delete	Registry Delete
Create Process	Network Connection Create
Terminate Process	Network Share Create
Access Process	Network Share Modify
Modify Process	Network Share Access
Director	Network
Service Create	System
Service Modify	IO Device
Load Module	Kernel
Window	Memory
Message	Other
Start Point	End Point

4.5 Markov Chain Analysis

Preliminary analysis with the markov chain is performed to gain additional insight on the behavior of the markov chain. Preliminary analysis was done using the equilibrium distribution of the markov chain, in-degree and out-degree of the nodes within the markov chain.

4.5.1 Equilibrium distribution. The equilibrium distribution is calculated and the probability of each node is converted into a graph for every step taken. Figure 2 shows the equilibrium distribution graph for the NanoCore malware family that have been constructed. It is observed that the markov chain is indeed able to achieve an equilibrium state.

The lines x-axis is the step of the traversal of the markov chain and the y-axis is the probability of occuring. The lines of the graph show the probability of each node occurring during each step of the markov chain traversal. For example, in graph 2 the red line is above the other lines throughout the traversal. That state is the

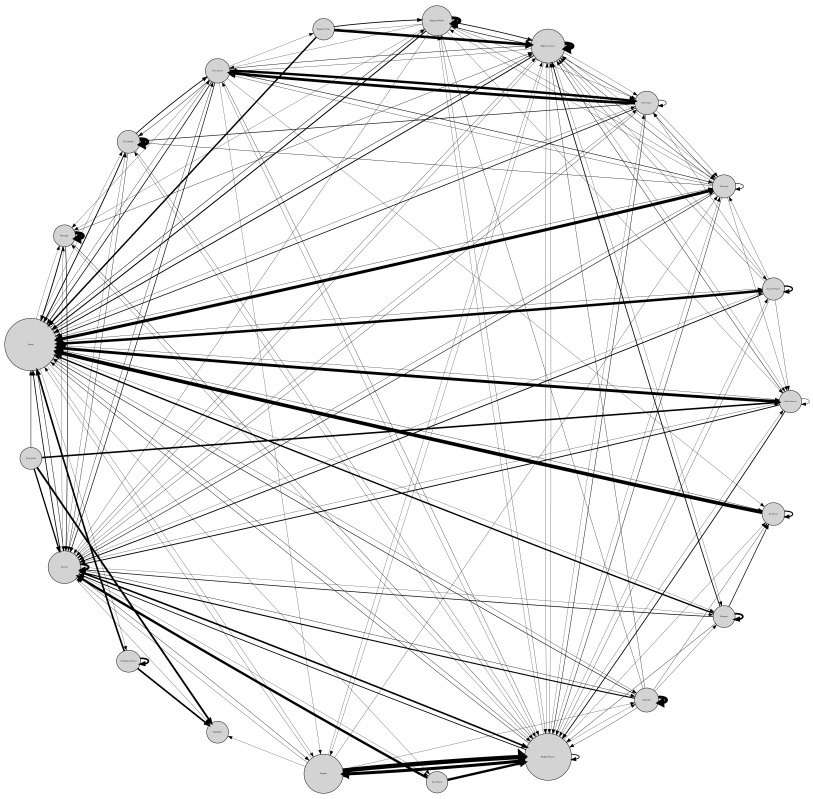

Figure 1: Graphical representation of the NanoCore API Call cateogry markov chain

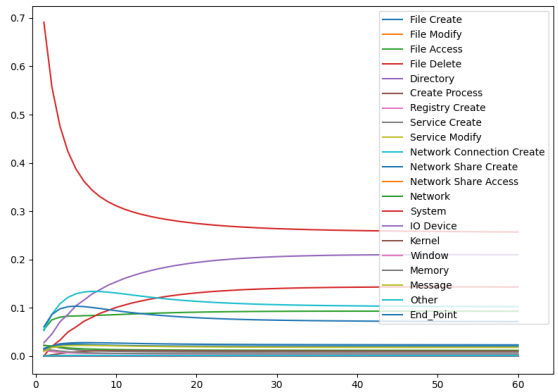

Figure 2: Equilibrium distribution graph of NanoCore malware markov chain

state that is most likely to occur during the execution and that it also has the highest frequency during the execution of the sample.

4.5.2 In-degree and Out-degree. The in-degree of a node within a directed graph is the number of incoming edges going into a node and the out-degree of a node is the number of outgoing edges from a node. This is a measure of connectivity for the nodes. Nodes that have a larger in-degree compared to an out-degree could be an indication of a more consistent pattern where the amount of possible category transitions are less. This pattern could indicate an exit point from a loop. Figure 3 shows a list of nodes within the markov chain where the in degree of a node is larger than the out degree of the node.


```
{"node": "System", "diff": 0.05000000000000044, "in degree": 0.8500000000000001, "out degree": 0.8}
{"node": "Modify Process", "diff": 0.05000000000000044, "in degree": 0.8, "out degree": 0.75}
{"node": "File Modify", "diff": 0.10000000000000003, "in degree": 0.35000000000000003, "out degree": 0.25}
{"node": "End_Point", "diff": 0.2, "in degree": 0.2, "out degree": 0.0}
{"node": "Registry Access", "diff": 0.14999999999999999, "in degree": 0.75, "out degree": 0.6000000000000001}
{"node": "Directory", "diff": 0.0, "in degree": 0.5, "out degree": 0.5}
{"node": "Kernel", "diff": 0.05000000000000044, "in degree": 0.9500000000000001, "out degree": 0.9}
{"node": "File Delete", "diff": 0.0, "in degree": 0.1, "out degree": 0.1}
{"node": "IO Device", "diff": 0.2000000000000004, "in degree": 0.3000000000000004, "out degree": 0.1}
{"node": "Create Process", "diff": 0.2, "in degree": 0.45, "out degree": 0.25}
{"node": "File Create", "diff": 0.04999999999999999, "in degree": 0.45, "out degree": 0.4}
{"node": "Message", "diff": 0.05000000000000044, "in degree": 0.3000000000000004, "out degree": 0.25}
```


Figure 3: List of nodes where in degree > out degree

4.6 Malware Classification

Table 7 shows the resulting f-score and accuracy of the classification process. For this experiment the confidence level of the identified and classified sample obtained from equation 2 must be larger than 0.6 in order to be identified and classified as the corresponding software category.

Table 7: API Call Categorization Threshold Values For Confidence > 0.6

Malware Family	F-score	Accuracy
GandCrab	0.947368	0.975
NjRAT	0.777778	0.9
Tinba	1.0	1.0
AveMariaRAT	0.666667	0.875
Ramnit	1.0	1.0
SmokeLoader	0.888889	0.95
NanoCore	0.888889	0.95
Zeus	1.0	1.0
AgentTesla	0.823529	0.925
Gh0st	0.625	0.7
Quakbot	1.0	1.0
Redline	0.947368	0.975
AZORult	0.166667	0.75
XMRig	0.571429	0.85
CoinMiner	0.333333	0.8
BlackShades	0.391304	0.38

5 EXPERIMENT ANALYSIS

5.1 Categorization Performance

The classification uses a total of 40 samples for each category and divided into 2 sets of samples. 10 samples are of the same family and 32 samples of different families. The f-score and accuracy for the malware classification has a large gap between the highest and lowest values, the lowest resulting f-score being 0.33 and the highest being 1.0. This shows that the process is not able to perform malware classification consistently. The performance of the proposed malware classification method is able to achieve an accuracy 87.19% . The performance of the proposed method fulfills the hypothesis of both classification accuracy of >80%.

5.2 Malware Behavior From Markov Chain

Equilibrium distribution and the degree centrality of the category was not able to provide sufficient insight on the behavior of the malware family. Both metrics provide some insight to the properties of the markov chain, but fails to indicate key behaviors of the malware family. Equilibrium distribution of the category transition probability graph shows the most likely category that the graph will end up given continuous traversal. This identifies the category with the highest probability, but does not identify if the category is part of the key operations or an obfuscation method performed by the malware. The degree centrality can identify potential convergence points in the runtime of the malware. The same issue still persist where it is unclear whether this particular property can identify key malware behavior.

6 CONCLUSION

An API call categorization system have been developed by using MITRE ATT&CK data sources and data components as a basis for the categories. Regular expressions are matched to API call names to categorize the API calls. Converting an API call sequence obtained from dynamic analysis and producing an API call category sequence, then using the API call category sequence to construct API call category transition probability graphs to identify and classify malware by using a similarity score and threshold values. The proposed method has been developed to successfully perform malware classification with an accuracy of 87.19%. For future research on this topic improvements could be made regarding the dataset and graph representation. Utilizing a larger dataset with a larger diversity of malware families is required to properly evaluate the performance of the system and exploring multiple graph representation of the API call category sequence can change the performance of the malware identification and classification.

REFERENCES

[1] Blake Anderson, Daniel Quist, Joshua Neil, Curtis Storlie, and Terran Lane. 2011. Graph-based malware detection using dynamic analysis. *Journal in Computer Virology* 7, 4 (2011), 247–258. https://doi.org/10.1007/s11416-011-0152-x

[2] AV-TEST. 2022. Malware Statistics & Trends Report | AV-TEST. https://www.av-test.org/en/statistics/malware/.

[3] Zhi Guo Chen, Ho Seok Kang, Shang Nan Yin, and Sung Ryul Kim. 2017. Automatic ransomware detection and analysis based on dynamic API calls flow graph. *Proceedings of the 2017 Research in Adaptive and Convergent Systems, RACS 2017* 2017-Janua (2017), 196–201. https://doi.org/10.1145/3129676.3129704

[4] Gianni D'Angelo, Massimo Ficco, and Francesco Palmieri. 2021. Association rule-based malware classification using common subsequences of API calls. *Applied Soft Computing* 105 (2021), 107234. https://doi.org/10.1016/j.asoc.2021.107234

[5] Sanchit Gupta, Harshit Sharma, and Sarvjeet Kaur. 2018. Malware Characterization Using Windows API Call Sequences. *Journal of Cyber Security and Mobility* 7 (2018), 363–378. https://doi.org/10.13052/jcsm2245-1439.741

[6] Weijie Han, Jingfeng Xue, Yong Wang, Lu Huang, Zixiao Kong, and Limin Mao. 2019. MalDAE: Detecting and explaining malware based on correlation and fusion of static and dynamic characteristics. *Computers and Security* 83 (2019), 208–233. https://doi.org/10.1016/j.cose.2019.02.007

[7] Weijie Han, Jingfeng Xue, Yong Wang, Fuquan Zhang, and Xianwei Gao. 2021. APTMalInsight: Identify and cognize APT malware based on system call information and ontology knowledge framework. *Information Sciences* 546 (2021), 633–664. https://doi.org/10.1016/j.ins.2020.08.095

[8] Youngjoon Ki, Eunjin Kim, and Huy Kang Kim. 2015. A novel approach to detect malware based on API call sequence analysis. *International Journal of Distributed Sensor Networks* 2015 (2015). https://doi.org/10.1155/2015/659101

[9] MalwareBytes Labs. 2021. 2021 State of Malware Report. *Malwarebytes* (2021), 1–65. https://resources.malwarebytes.com/resource/2019-state-malware-malwarebytes-labs-report/

[10] Alejandro Martín, Víctor Rodríguez-Fernández, and David Camacho. 2018. CANDYMAN: Classifying Android malware families by modelling dynamic traces with Markov chains. *Engineering Applications of Artificial Intelligence* 74, July 2017 (2018), 121–133. https://doi.org/10.1016/j.engappai.2018.06.006

[11] Mitre. 2022. Data Sources | MITRE ATT&CK®. https://attack.mitre.org/datasources/

[12] Mitre. 2022. MITRE ATT&CK®. https://attack.mitre.org/

[13] Lucky Onwuzurike, Enrico Mariconti, Panagiotis Andriotis, Emiliano De Cristofaro, Gordon Ross, and Gianluca Stringhini. 2019. Mamadroid: Detecting android malware by building Markov chains of behavioral models (extended version). *ACM Transactions on Privacy and Security* 22, 2 (2019). https://doi.org/10.1145/3313391 arXiv:1711.07477

[14] Homer Pacag. 2020. Phishing Attacks Discovered Using Coronavirus Theme | Trustwave. https://www.trustwave.com/en-us/resources/blogs/spiderlabs-blog/multiple-phishing-attacks-discovered-using-the-coronavirus-theme/

[15] Younghee Park, Douglas S. Reeves, and Mark Stamp. 2013. Deriving common malware behavior through graph clustering. *Computers and Security* 39, PART B (2013), 419–430. https://doi.org/10.1016/j.cose.2013.09.006

[16] Neha Runwal, Richard M. Low, and Mark Stamp. 2012. Opcode graph similarity and metamorphic detection. *Journal in Computer Virology* 8, 1-2 (2012), 37–52. https://doi.org/10.1007/s11416-012-0160-5

[17] Jakapan Suaboot, Zahir Tari, Abdun Mahmood, Albert Y. Zomaya, and Wei Li. 2020. Sub-curve HMM: A malware detection approach based on partial analysis of API call sequences. *Computers and Security* 92 (2020), 101773. https://doi.org/10.1016/j.cose.2020.101773

[18] Tobias Wüchner, Martín Ochoa, and Alexander Pretschner. 2014. Malware detection with quantitative data flow graphs. *ASIA CCS 2014 - Proceedings of the 9th ACM Symposium on Information, Computer and Communications Security* (2014), 271–282. https://doi.org/10.1145/2590296.2590319

Deep Learning Analysis in Development of Handwritten and Plain Text Classification API

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ABSTRACT

Optical Character Recognition (OCR) and Handwritten Text Recognition (HTR) are technologies that enable text recognition. The difference between OCR and HTR is one designed specifically for digital text and one designed for handwritten text. There are already various implementations of OCR and HTR online. However, such systems do not guarantee the systems are in premises. To solve this problem, the OCR and HTR system must be built from the scratch.

The purpose of this research is to improve the recognition by separating the text whether it is a handwritten or a printed text, which will later be forwarded into the appropriate recognition system. An application program interface (API) was also created in order to finalize the classification system into real world usage. In this research, the classification system being developed using convolutional neural network (CNN) method. To be able to reach the highest accuracy of the classification system, the experimentation and improvement on hyperparameters, dataset format, data augmentation and analysis on 3 CNN architectures were conducted. In the end of this research, there are 2 architectures in a tight competition on ideal data testing, one is VGG-16 with 90.63% accuracy and one is AlexNet with 90.17% accuracy. However, AlexNet is chosen as the winner after real data testing.

CCS CONCEPTS

• **Computer systems organization** → Architectures; • **Information systems** → Data management systems; World Wide Web.

KEYWORDS

API, CNN, HTR, in premises, OCR text classification, Text categorization

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1 INTRODUCTION

The standard process of data fulfilment of insurance registration usually requires applicants to write down the data manually on a paper and the data will be inputted to a computer by the insurance agent, which may be time consuming. The aforementioned problem can be simplified by using an OCR and HTR. Such system is already publicly available and can be downloaded from the internet. However, some documents or information are credential and the output from existing applications cannot be used to automate data submission. Therefore, the system needs to be on premises to ensure the data do not leak and the output need to be as a data structure like JSON or XML to make an ease of data forwarding. To satisfy these conditions, the system needs to be built from scratch rather than using existing OCR and HTR APIs, libraries, or application. There are 2 ways of how the image being taken to be processed in OCR and HTR system. The first is to use mobile phone camera to take a picture of the filled documents and the second is by scanning filled documents using a flatbed scanner, which imply there is a need of a computer. For the reason of convenient and less cost, mobile phone is chosen as preferred device. There are several challenges while taking a picture from a mobile phone camera: the image may be blurry, light can be reflected and has low density in some low-end mobile device. Later on, the pictures taken will be pre-processed, classified and recognized in the server for the reason of ease of update and avoid huge utilization of storage and memory in mobile phone.

Classifying printed text and handwritten text is one solution to improve character recognition. As Zagoris [1] said, the reason they are being classified is because the treatment to each category is different and according to Kaur [2], by differentiating them it will increase the performance and system quality. This project covers the work of classification on handwritten text and printed

Table 1: Comparison of SVM and CNN research and their results

Works By	Basarkar [4]	Huang and LeCun [3]		This Research
Case Study	Multi Class Image Classification	Multi Class Image Classification		Binary Class Image Classification
Method	SVM	SVM	CNN	CNN
Accuracy Result	86%	56.6% (JC) 88.4% (U)	83.62% - 92.8% (JC) 89.6% - 93.8% (U)	Expected: More than 86%
Speed Result (sec)	-	2.2	0.04	-

text system. The classification will use deep learning since the documents in the future will be varies and by using deep learning, the system will be able to predict any documents, regardless the type of documents received. The deep learning is selected over machine learning because as Huang and LeCun [3] studied, it is faster and more accurate. In additional, an API will be created to facilitate other user to continue to the recognition step.

2 RELATED WORKS

Basarkar [4] used SVM as the primarily usage of SVM is to classify tasks on complex data such as image classification. This algorithm uses hyperplane to give some margin between data of two categories. The research shows for text classification, SVM outperformed Naïve Bayes, Rocchio, C4.5, and k-NN in terms of accuracy. The research from Huang and LeCun [3] shows that SVM computation is intensive and scales badly along larger dataset (105 - 106 samples) and comparing the CNN. The research on large scale generic data from NORB dataset shows that CNN outperformed SVM for both NORB jittered-cluttered (JC) and normalized-uniform (U) dataset. The result of their research can be seen in table 1. Based on this table, this research is expected to have more than 86% accuracy comparing the SVM method from work of Basarkar [4].

3 PROPOSED METHODOLOGY

The proposed methodology (figure 1) start with a preliminary research on deep learning framework and deep learning architectures to be used. The researcher then performs experiments to explore about the framework, hyperparameters and data behaviour. Thereafter, the researcher prepares datasets to be used in the training and validation data. Next, the researcher design and create the deep learning program and continue to the configuration and analysis phase. In the analysis phase, the researcher compares deep architecture by evaluating and validating each of the architecture to be able to conclude which architecture has the highest accuracy.

After selecting the deep learning architecture, the researcher continues to develop API program and conducts real environment testing, it covers testing on real image taken from mobile phone in every selected deep learning architectures and lastly test the API program.

4 ANALYSIS AND DISCUSSION

4.1 Preliminary Research

4.1.1 Research on Deep Learning Framework. There are 3 machine learning tools which are Microsoft CNTK, TensorFlow, and Theano.

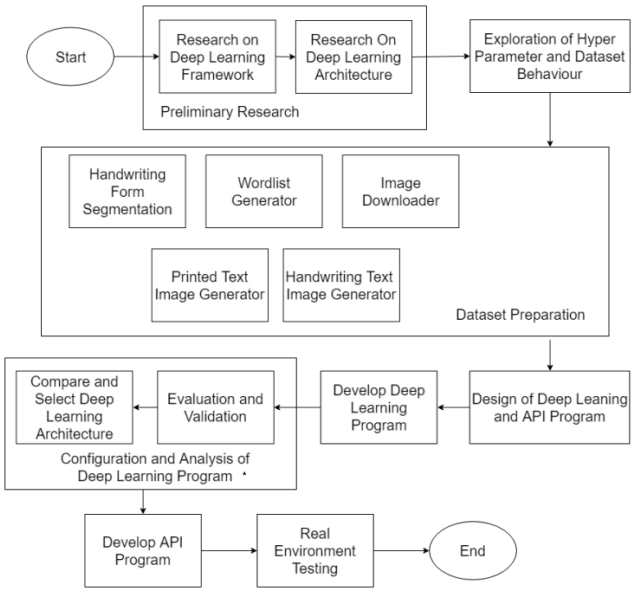

Figure 1: Proposed Methodology

In terms of speed of processing time, CNTK is the best tools, followed by TensorFlow. Although CNTK outperformed TensorFlow, the TensorFlow is easier to use since it interfaces Python and C++ language while CNTK uses its own file configuration to run the program, hence it is easier to debug the experiment in high level in TensorFlow and due to this consideration, TensorFlow is chosen as the framework for this project.

4.1.2 Research on Deep Learning Architecture. Between 3 deep neural network architecture being researched (RNN, CNN and MLP). According to Lyu [5], in terms of decoding or making prediction performance, RNN is the best in accuracy followed by CNN and MLP. RNN is more powerful than CNN due to wider feature extraction detail which contains time-variant factor, which also imply RNN has more computational overhead. The usage of RNN to a binary image classification problem is too powerful and not on target because the handwritten and printed text classification does not require time-variant factor, e.g. voice recognition. In the other hand, CNN is more typical and suitable to be used for image classification, as it said by Hoffmann [6].

Table 2: Experiment result on epochs and learning rate. The learning rate is denoted by LR, the training is denoted by Tr, the validation is denoted by Va, and the accuracy is denoted by Acc

		Epochs								
LR		**50**			**100**			**500**		
	0.01		**Acc**	**Loss**		**Acc**	**Loss**		**Acc**	**Loss**
		Tr	0.4833	1.095	**Tr**	0.4792	1.067	**Tr**	0.5208	0.9001
		Va	0.5938	0.8761	**Va**	0.4375	1.489	**Va**	0.3688	1.009
	0.0001		**Acc**	**Loss**		**Acc**	**Loss**		**Acc**	**Loss**
		Tr	0.7250	0.5405	**Tr**	0.7431	0.5280	**Tr**	0.8125	0.4303
		Va	0.7312	0.5250	**Va**	0.7437	0.4717	**Va**	0.7875	0.4380

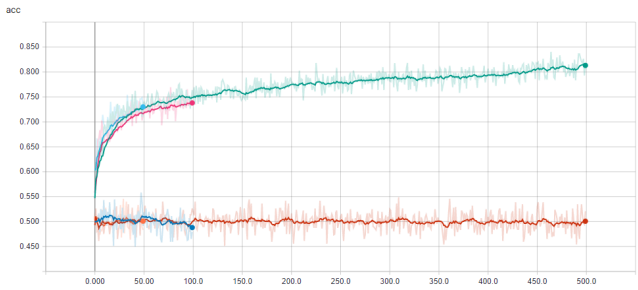

Figure 2: Training accuracy comparing several epochs and learning rate. The Y axis shows the accuracy (1 = 100%) while the X axis shows the epochs. The legend shows learning rate (lr) and number of epochs (e)

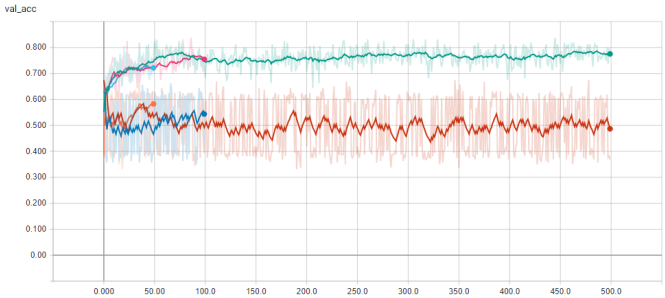

Figure 3: Validation accuracy graph comparing several epochs and learning rate. The Y axis shows the accuracy (1 = 100%) while the X axis shows the epochs. The legend shows learning rate (lr) and number of epochs (e)

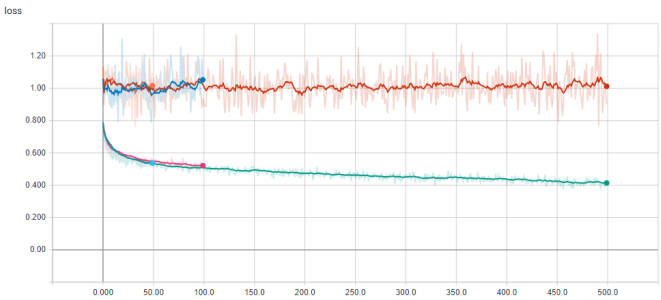

Figure 4: Training loss graph comparing several epochs and learning rate. The Y axis shows the loss while the X axis shows the epochs. The legend shows learning rate (lr) and number of epochs (e)

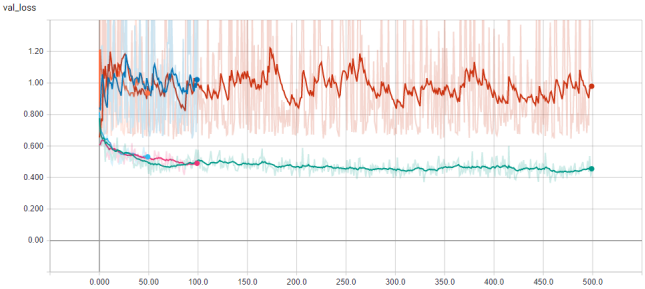

Figure 5: Validation loss graph comparing several epochs and learning rate. The Y axis shows the loss while the X axis shows the epochs. The legend shows learning rate (lr) and number of epochs (e)

4.2 Exploration of Hyperparameters and Dataset Behavior

4.2.1 Impact of Hyperparameters.. As the hyperparameters being tuned in this project were learning rate and epochs. The experiments conducted was using combination of 50, 100 and 500 epochs and 0.01 and 0.0001 learning rate. The experiment result can be seen in table 2 and to make the numbers being more intuitive, a comparison graphs also provided in figure 2, 3, 4 and 5.examples.

The conclusion can be taken from the experiment was low learning rate has a significant improvement to the accuracy and loss in a neural network. Higher epochs increase the accuracy and reduces the loss slowly overtime.

4.2.2 Data Augmentation. The experiment conducted using small number of datasets, the analysis in the TensorBoard showed that the training had 99.99% accuracy (figure 6) while the loss was 0.0014 (figure 7).

The prediction were incredibly good when the testing images has similar rotation, scale and background. However, the prediction decreased very much and even lead to wrong prediction when the testing image was rotated, scaled smaller and had new background.

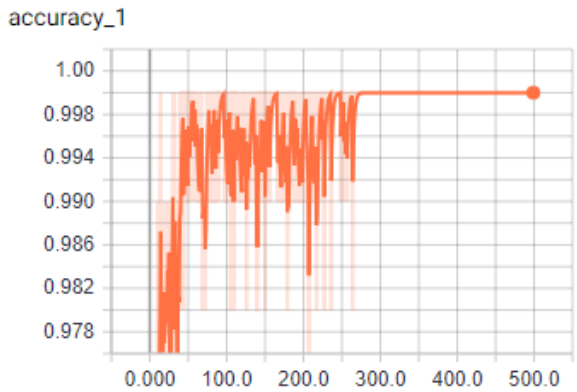

Figure 6: Accuracy graph for dolls classification. The Y axis shows the accuracy (1 =100% accuracy) while the X axis shows the eopchs

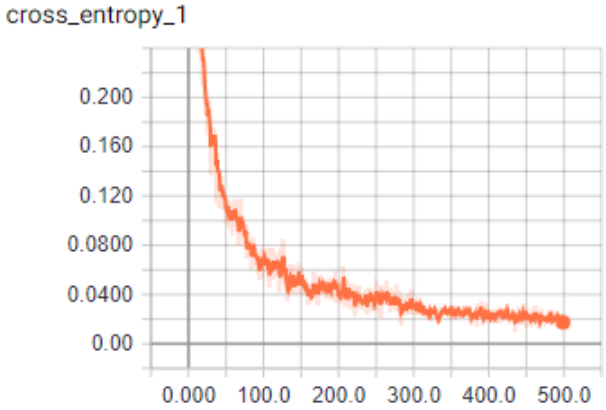

Figure 7: Loss graph for dolls classification. The Y axis shows the loss while the X axis shows the epochs

Figure 8: Original image before data augmentation

It was expected since the images had not learned about these features. More variance of data needed to learn more features and one way to increase the data variety is explained by Krizhevsky and Hinton [7]. It is by doing data augmentation. The first form of data augmentation is image translations and horizontal reflections, the second form of data augmentation is altering RGB intensity of the image. Figure 9 shows 20 images generated after applying data augmentation of rotation, shifting, scaling, flipping and zooming from the original image (figure 8).

Figure 9: Images after data augmentation. The augmentation contains rotation, shifting, scaling, flipping and zooming

Table 3: Architecture of LeNet-5

Number	Layer
1	Convolution 2D
2	Batch Normalization
3	Max Pooling 2D
4	Convolution 2D
5	Batch Normalization
6	Activation
7	Max Pooling 2D
8	Flatten
9	Dense
10	Activation
11	Dense
12	Batch Normalization
13	Activation

4.3 Configuration and Analysis of Deep Learning Program

4.3.1 Evaluation and Validation. The evaluation used training datasets and the validation used validation datasets. The validation occurs for each iteration the neural network being evaluated. It was based on directory name. Therefore, there were parent directories created: validation and training. The handwritten and plain text directory were created inside those directories. All images were taken from the main collection of datasets created and randomly-uniquely copied to the corresponding directory. All of these processes were happened by hooking the directory names to the TensorFlow training process. All of the training hyperparameters were using 60 epochs and 0.0001 learning rate. These values were decided after some manual tunings on the neural network configuration.

4.3.2 LeNet-5. The experiment began with LeNet-5 architecture. The total number of trainable parameters from this training was 37,528,216. The architecture of the LeNet-5 can be seen in table 3.

The result of the training can be seen in table 4. It can be concluded that there still an indication of overfitting because there still a gap between the accuracy and loss result from the training and validation. The model may also hardly improve as the slope started to incline slowly or perhaps already near to the peak (see figures in section 4.3.5).

Table 4: Accuracy and loss result for training and validation of LeNet-5

	Accuracy	Loss
Training Data	0.8913	0.3130
Validation Data	0.8638	0.3477

Table 5: Architecture of AlexNet

Number	Layer		
1	Convolution 2D	18	Batch Normalization
2	Activation	19	Flatten
3	Max Pooling 2D	20	Dense
4	Batch Normalization	21	Activation
5	Convolution 2D	22	Dropout
6	Activation	23	Batch Normalization
7	Max Pooling 2D	24	Dense
8	Batch Normalization	25	Activation
9	Convolution 2D	26	Dropout
10	Activation	27	Batch Normalization
11	Batch Normalization	28	Dense
12	Convolution 2D	29	Activation
13	Activation	30	Dropout
14	Batch Normalization	31	Batch Normalization
15	Convolution 2D	32	Dense
16	Activation	33	Activation
17	Max Pooling 2D		

Table 6: Accuracy and loss result for training and validation of AlexNet

	Accuracy	Loss
Training Data	0.8584	0.3341
Validation Data	0.9017	0.2363

4.3.3 AlexNet. The total numbers of the trainable parameter being learned from this architecture was 28,060,618. The architecture of the AlexNet can be seen in table 5.

The result of the accuracy and loss from the training and validation can be seen in table 6. It can be concluded that the model being well trained. The model may also capable to be improved by extending the epochs as the accuracy slope still inclining (see figures in section 4.3.5).

4.3.4 VGG-16. The total numbers of the parameter being learned from this architecture was 69,257,026. The architecture of the VGG-16 can be seen in table 7

The result of the accuracy and loss from the training and validation can be seen in table 8. It can be concluded that the model was very well trained. The model may also capable to be improved by extending the epochs as the accuracy slope still inclining (see figures in section 4.3.5)

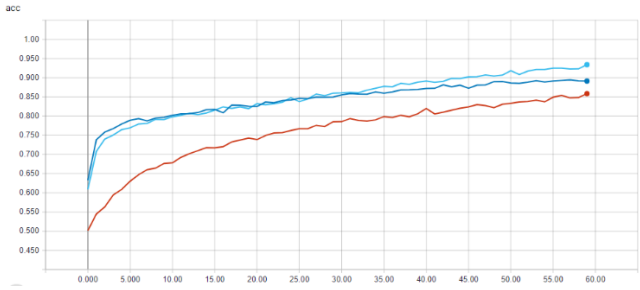

Figure 10: Training accuracy comparison between LeNet-5 (0.8913), AlexNet (0.8584) and VGG-16 (0.9340). The VGG-16 has the highest accuracy followed by LeNet-5 and AlexNet

4.3.5 Comparison and Analysis. Figure 10 and 11 show the accuracy graphs while figure 12 and 13 show the loss graph from training and validation results.

The ranking of each architecture from training and validation accuracy and loss can be seen in table 9 and 10. It can be seen that VGG-16 is the first rank along the accuracy and loss.

The total number of trainable parameters comparison table can be seen in table 11. As it can be seen, there is a great difference between VGG-16 and another architecture.

The conclusion that can be drawn from the data above is that the VGG-16 outperformed AlexNet and LeNet-5. However, the fact that the VGG-16 learned a lot of parameter also may restricted the model

Table 7: Architecture of VGG-16

Number	Layer	12	Convolution 2D
1	Input Layer	13	Convolution 2D
2	Convolution 2D	14	Convolution 2D
3	Convolution 2D	15	Max Pooling 2D
4	Max Pooling 2D	16	Convolution 2D
5	Convolution 2D	17	Convolution 2D
6	Convolution 2D	18	Convolution 2D
7	Max Pooling 2D	19	Max Pooling 2D
8	Convolution 2D	20	Flatten
9	Convolution 2D	21	Dense
10	Convolution 2D	22	Dense
11	Max Pooling 2D	23	Dense

Table 8: Accuracy and loss result for training and validation of VGG-16

	Accuracy	Loss
Training Data	0.9340	0.1753
Validation Data	0.9063	0.2296

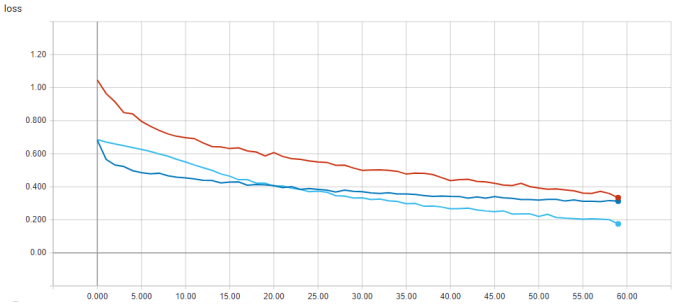

Figure 11: Validation accuracy comparison between LeNet-5 (0.8638), AlexNet (0.9017) and VGG-16 (0.9063). The VGG-16 has the highest accuracy followed by AlexNet and LeNet-5

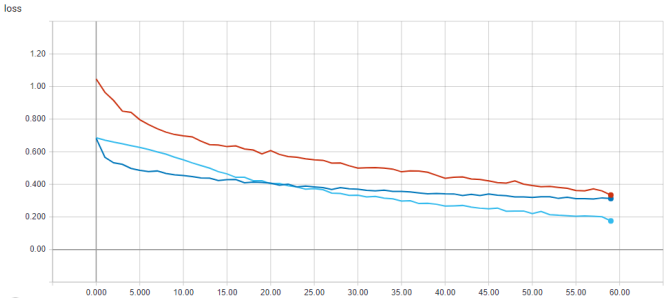

Figure 12: Training loss comparison between LeNet-5 (0.3130), AlexNet (0.3341) and VGG-16 (0.1753). The VGG-16 has the lowest loss followed by LeNet-5 and AlexNet

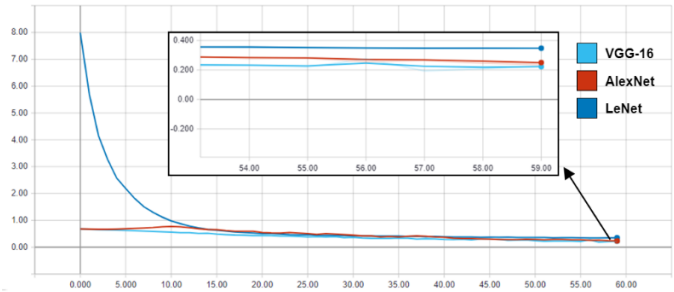

Figure 13: Validation loss comparison between LeNet-5 (0.3477), AlexNet (0.2363) and VGG-16 (0.2296). The VGG-16 has the lowest loss followed by AlexNet and LeNet-5

Table 9: Ranking of training and validation accuracy between LeNet-5, AlexNet and VGG-16

Ranking	Training Accuracy	Validation Accuracy
1	VGG-16	VGG-16
2	LeNet-5	AlexNet
3	AlexNet	LeNet-5

Table 10: Ranking of training and validation loss between LeNet-5, AlexNet and VGG-16

Ranking	Training Loss	Validation Loss
1	VGG-16	VGG-16
2	LeNet-5	AlexNet
3	AlexNet	LeNet-5

to very specific content formats in images, it gives no space for error or cannot generalized well. In the other hand, the AlexNet might be more preferable for real environment because it has lesser trainable parameters among all architectures and is rank second in the validation.

Table 11: Comparison of total number of trainable parameters between LeNet-5, AlexNet and VGG-16

	LeNet-5	AlexNet	VGG-16
Total number of trainable parameters	37,528,216	28,060,618	69,257,026

Table 12: Real environment testing comparison using LeNet-5, AlexNet and VGG-16. The testing of 1 device was using 30 images taken from the device camera

	LeNet-5	AlexNet	VGG-16
Xiaomi Redmi Note 4	15/30 (50%)	21/30 (70%)	15/30 (50%)
iPhone 7	15/30 (50%)	22/30 (73.33%)	15/30 (50%)

Figure 14: Pre-processed handwritten image captured from Xiaomi Redmi Note 4

Figure 15: Pre-processed printed text image captured from Xiaomi Redmi Note

Figure 16: Pre-processed handwritten image captured from iPhone 7

5 REAL ENVIRONMENT TESTING AND API

The real environment testing was conducted using 2 mobile devices. One was XiaoMi Redmi Note 4 and one was iPhone 7. The testing used 30 images captured from each device. Below are sample of images being used for the testing. Figure 14 and figure 15 show image of handwritten and printed text captured from Xiaomi Redmi Note 4, figure 16 and 17 show image of handwritten and printed text captured from iPhone 7.

Figure 17: Pre-processed printed text image captured from iPhone 7

Figure 18: Image comparison of printed text training data (left) testing data (right). The dot or noise in the testing data called salt and pepper noise

The testing using LeNet-5 and VGG-16 resulted to 15/30 (50%) correctness for both Xiaomi Redmi Note 4 and iPhone 7. The testing using AlexNet resulted to 21/30 (70%) correctness for Xiaomi Redmi Note 4 and 22/30 (73.33%) for iPhone 7. As it said before, the AlexNet can generalized better since the total number of parameters was fewer. The accuracy result of the testing can be shown in table 12. The general weakness of the models was on predicting the printed text and if there were salt and pepper noises in the image. Since in the training data, the stroke for printed text was smoother as they were coming from generated digital character and in both training and validation data, there were no salt and pepper noise included (see figure 18 for the comparison).

In additional, an API program was created and tested. The API created on the top of Flask framework while the testing covers the reliability of the program; it must show same result in different devices and when the system restarted, it must have same result.

6 CONCLUSIONS

As the conclusion, although VGG-16 outperformed AlexNet on ideal data testing, AlexNet is better on facing real data. Therefore,

the most accurate selected deep learning algorithm to classify handwritten and printed text is CNN – AlexNet with 73.33% accuracy on real data and 90.17% on ideal data testing. In additional, the deep learning and API program are created on-premises and the API successfully created to interface the deep learning program.

REFERENCES

[1] Konstantinos Zagoris, *et al.*, 2001. Distinction between handwritten and machine-printed text based on the bag of visual words model. Pattern Recognition. 47, 3 (Mar, 2014). 1051-1062. DOI: https://doi.org/10.1016/j.patcog.2013.09.005.

[2] Manpreet Kaur, 2016. A Technique for Classification of Printed & Handwritten text. Research Cell: an International Journal of Engineering Sciences. 21. 123-128.

[3] Fuu Jie Huang and Yann LeCun. 2006. Large-scale Learning with SVM and Convolutional Nets for Generic Object Categorization. In 2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. 284-291

[4] Ankit Basarkar., 2017. Document Classification Using Machine Learning. Master Thesis.San Jose State University

[5] Wei Lyu, *et al.*, 2018. Performance evaluation of channel decoding with deep neural networks.

[6] Javier Hoffmann,. *et al.* 2017. A Survey on CNN and RNN Implementations.

[7] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E. Hinton, 2012. ImageNet Classification with Deep Convolutional Neural Networks. In Advances in Neural Information Processing Systems 25 (NIPS 2012) 1-9.

Analysis of Tuberculosis Disease Spreading Pattern in Muara Enim District using KNN Algorithm

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ABSTRACT

Tuberculosis (TB) is a type of infectious disease caused by Mycobacterium tuberculosis, which not only attacks the lungs, but can also attack the bones, intestines, or glands. During the Covid-19 pandemic, TB cases in Indonesia also increased. TB and Covid-19 had the similar symptoms such as cough, fever, and breathing difficulty, so that TB sufferers must be given serious treatment to avoid Covid-19. In predicting a disease, it is important for health workers to make decisions, thus it is necessary to do an early diagnosis in order to reduce the transmission of TB in the community. There are many algorithm methods used in conducting data analysis, for this study the authors use K-Nearest Neighbor (K-NN) algorithm and Logistic Regression as comparison. Experimental results using available dataset collected from health centers in Muara Enim District of South Sumatra Province show that the K-NN algorithm provides the best accuracy of 89% on dataset with training to testing data ratio of 80%:20%, while the Logistic Regression provides the best accuracy of 96% on 70%:30% ratio. The analysis mechanism discussed in this paper may be considered as tool for the authority to predict and take necessary actions to prevent the TB spreading.

CCS CONCEPTS

• **Computing methodologies**; • **Machine learning**;

KEYWORDS

TB, Logistic Regression, K-Nearest Neighbor

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1 INTRODUCTION

Tuberculosis (TB) is a type of infectious disease caused by Mycobacterium tuberculosis, which not only attacks the lungs, but can also attack the bones, intestines, or glands. World Health Organization (WHO) has declared TB as a global emergency. TB is still a threat to countries in the world and needs to be eradicated optimally. Symptoms such as fever, cough, chest pain and shortness of breath are things that cause TB disease. In Indonesia, TB is ranked as the second dangerous infectious disease with 845, 000 cases and 98,000 deaths. The Indonesian government attempts to reduce the number of TB sufferers by 2030 by means of prevention, diagnosis, treatment, and providing health services for all TB sufferers. During the pandemic, TB cases in Indonesia increased, TB and Covid-19 had the same symptoms such as cough, fever, and difficulty breathing. So that TB sufferers must be given serious treatment to avoid Covid-19 [1].

Because this disease is contagious, a system is needed to predict the spread of TB cases, one of which is making predictions using data science techniques. In predicting a disease, it is important for health workers to make decisions, thus it is necessary to perform an early diagnosis based on appearing symptoms, in order to reduce the transmission of TB in the community. There are many algorithms used in conducting data analysis. The K-Nearest Neighbor (K-NN) algorithm is one of the popular methods in data classification. This algorithm is very suitable to be used because it is easy to implement in diagnosing a disease, K-NN is usually applied in data classification based on the value of K, i.e.: the value of the nearest neighbor [5]. Because it is only seen from the value of the nearest neighbor, this algorithm is called lazy learning [6]. Besides, K-NN is also effective if implemented on large training data [7]. Logistic Regression Algorithm is the most famous machine learning algorithm after Linear Regression. The algorithm is also used for classification tasks [8] and commonly used in the approach to make a predictive model of an event [9].

A previous study on warts disease analysis using K-NN obtained an accuracy of 90.90% [2]. Another study on heart disease analysis using the K-NN algorithm provided an accuracy of 96.66% [3]. A research work using the Logistic Regression algorithm on cardiovascular disease analysis obtained an accuracy of 87.10% [4].

Based on previous research works mentioned above, the authors are interested in choosing the K-NN algorithm for this study and use the Logistic Regression as comparison to analyze and predict the spread of TB cases.

The rest of the paper is arranged as follows. Section 2 discusses the research method along with the dataset for the experiment. Section 3 presents the experimental results and discussion, and lastly, Section 4 provides the conclusion and future work.

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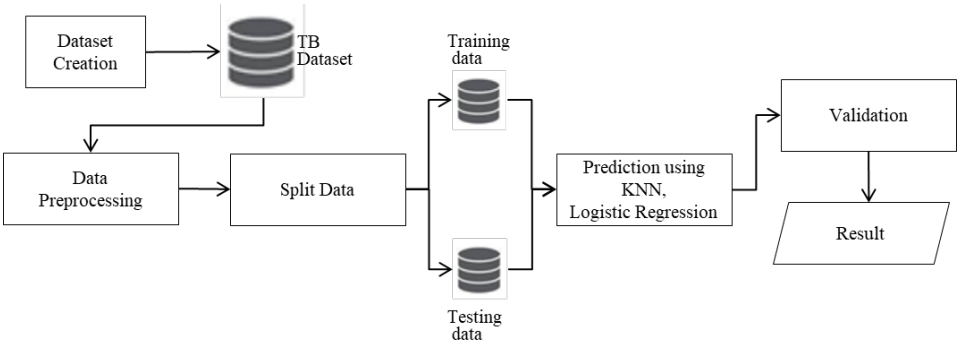

Figure 1: The proposed research method

2 RESEARCH METHOD

Figure 1 depicts the work flow of the proposed research method. The first step is to construct TB disease spreading dataset. The raw data is obtained from the Unit of Health, Muara Enim District. Then the raw data was cleaned through a data preprocessing. The clean dataset are then split into training and testing dataset. Next step is implementation of the KNN and Logistic Regression algorithms followed by experimentation and validation using K-fold Cross Validation. The last step is to report the experimentation results in terms of accuracy and other performance metrics.

2.1 Dataset

The data are collected from 40 healthcare centers in the district. After data cleaning process, the dataset consists of 640 rows. Each row has 9 attributes, i.e.: Health center name, category, age, gender, type of patient (new patient, relapse patient, patient with TB disease history other than relapse, patient without treatment history), and number of patients.

2.2 Data Split

Types of data in the dataset are already in numeric format, thus no data conversion is performed during the preprocessing. The preprocessing data involves normalization and completing the missing data only. Next is dataset description process and determine the dependent variable and independent variables. The dataset is split with three scenarios for the ratio of training and testing data as follows: 90%:10%, 80%:20% and 70%:30%. The dataset description is shown in Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6. The figures show the increase trend of TB disease sufferers.

Figure 2 sows the correlation test among variables, generated by Heatmap.

2.3 K-Nearest Neighbor

K-Nearest Neighbor (KNN) is a type of classification algorithm by determining the value of the nearest neighbor. The KNN algorithm was chosen because it has advantages such as easy to understand and implement, very fast and effective training if the training data is large enough. One of the weaknesses of this algorithm is that it is necessary to determine the value of the K parameter, namely the number of nearest neighbors. To use this algorithm, it is necessary

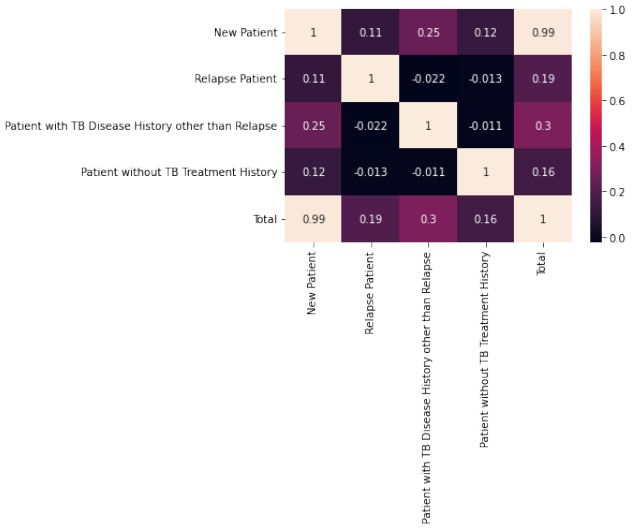

Figure 2: Correlation among features/attributes

to initialize the K parameter [12], in this study the K value used is K = 1 to K = 9, and obtain the K value with the best accuracy. Euclidean distance is the most commonly used distance calculation in the KNN algorithm (1).

$$d(x,\ y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \tag{1}$$

x_i = sample data
y_i = testing data
i = variable data
d(x, y) =dissimilarity/distance
n = data dimension

2.4 Logistic Regression

Logistic Regression is a classification algorithm to find the relationship between discrete/continuous features (input) with the probability of certain discrete OUTPUT results and is part of the regression analysis used when the dependent variable (response) is a dichotomous variable that has a value of 0 or 1 [10]. The result variable is

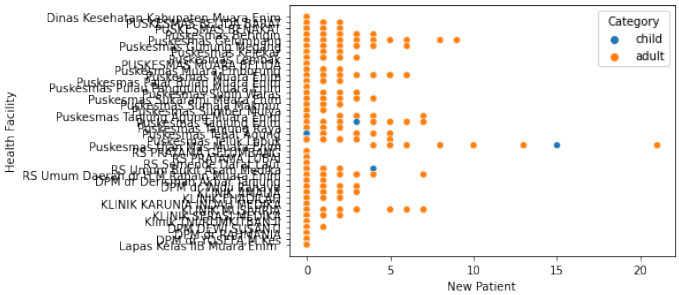

Figure 3: Scatterplot of New Patient

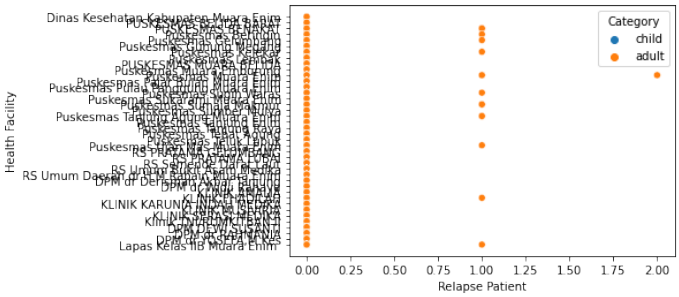

Figure 4: Scatterplot of Relapse Patient

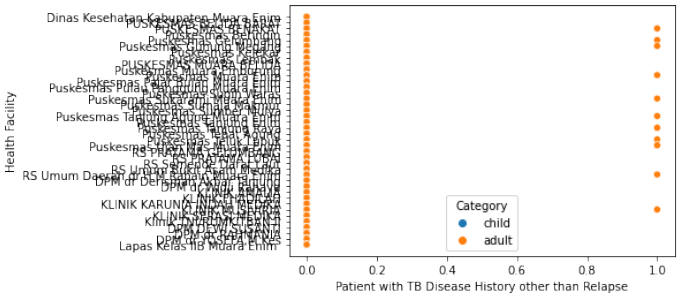

Figure 5: Scatterplot of patient with TB disease history other than relapse

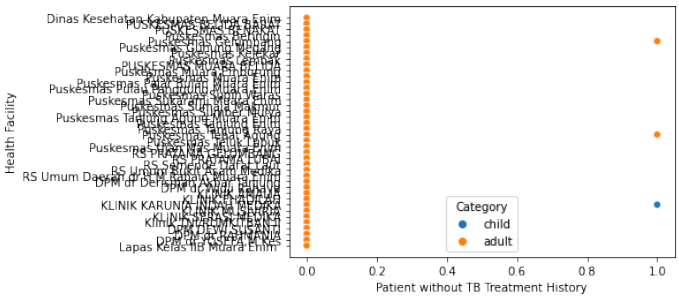

Figure 6: Scatterplot of patient without TB treatment history

Table 1: Accuracy for K=4

Scenario	Training	Testing
90%:10%	0.97	0.92
80%:20%	0.97	0.91
70%:30%	0.97	0.93

dichotomous which has two possibilities, yes or no, this algorithm can be used to detect TB disease [11]. The equation for Logistic Regression is shown in (2) [16].

$$Ln\left(\frac{p}{1-p}\right) = B_0 + B_1X \tag{2}$$

B_0 = constant
B_1 = coefficient of each variable
The p value or probability (Y =1) can be determined by (3).

$$p = \frac{e^{(B_0 + B_1X)}}{\left(1 + e^{(B_0 + B_1X)}\right)} \tag{3}$$

2.5 k-Fold Cross Validation

k-Fold Cross Validation is one method that is commonly used in model selection [13]. k-Fold Cross Validation increases the flexibility of the selected model and obtains maximum accuracy results [14]. Its function is to divide the data sample randomly and group the data as many as the k value. In machine learning, the k value that is often used is 10 [15].

3 EXPERIMENTAL RESULTS AND DISCUSSION

As mentioned in Section 2.2, the experiments use three data split scenarios for training data and testing data. The experiments are carried out on a computer with the following specifications. Processor 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz, 8 GB RAM, running Windows 11 operating system and Python language programming on *Google Colab* platform.

3.1 K-Nearest Neighbor Implementation

The KNN algorithm is implemented using Skicit learn library. Table 2 shows the accuracy for K=4 on training data and testing data. The testing with the value of K = 4 is considered based on the number and size of the data dimensions. The more data used, the lower the value of K. The larger the data dimension the higher the value of K chosen.

Next, performing experiments for variant values of K (from K=1 to K=9) for each dataset ratio scenario. Accuracy for variant values of K on the testing dataset is shown in Figure 7 to Figure 9. The best accuracy for 90% to 10% ratio of dataset is achieved for K=1, i.e.: 0.95 (see Figure 7). The best accuracy for 80% to 20% ratio of dataset is also achieved for K=1, i.e.: 0.94 (see Figure 8). 70% to 30% ratio of dataset is also achieved for K=1, i.e.: 0.96 (see Figure 9). Table 2 summarizes the best accuracy during the testing for each algorithm and for each scenario.

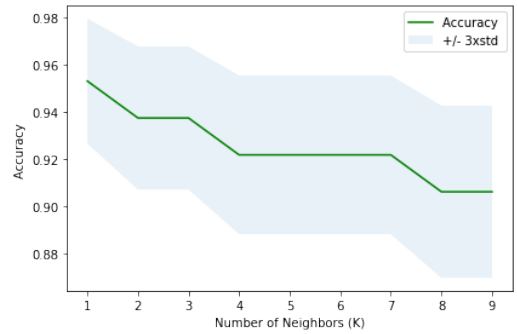

Figure 7: Accuracy for variant values of K on 70%:30% ratio

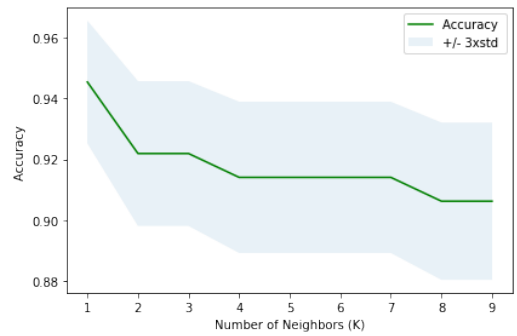

Figure 8: Accuracy for variant values of K on 80%:20% ratio

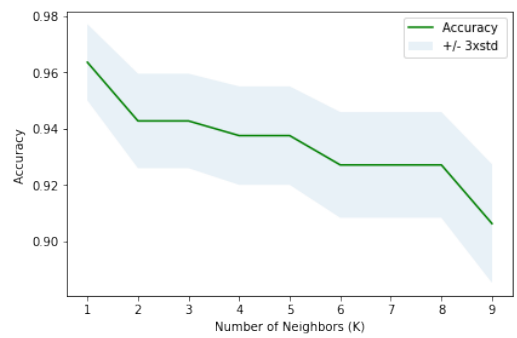

Figure 9: Accuracy for variant values of K on 90%:10% ratio

Table 2: Overall Accuracy Result of KNN Algorithm

Dataset ratio	The best value of K	Training Accuracy	Testing Accuracy
90%:10%	K=1	1.0	0.95
80%:20%	K=1	1.0	0.94
70%:30%	K=1	1.0	0.96

Table 3: Overall Accuracy Result of Logistic Regression Algorithm

Dataset ratio	The best value of K	Training Accuracy	Testing Accuracy
90%:10%	K=1	1.0	82.81
80%:20%	K=1	1.0	89.84
70%:30%	K=1	1.0	77.08

Table 4: Accuracy comparison

Dataset ratio	Logistic Regressiom	K-Nearest Neighbor
90%:10%	82%	95%
80%:20%	89%	94%
70%:30%	77%	96%

3.2 Logistic Regression Implementation

Experimental results during testing for Logistic Regression algorithm are shown in Table 3.

3.3 k-Fold Cross Validation Result

The KNN and Logistic Regression algorithms are validated using 10-Fold cross validation method with random state 1 and the results are shown in Table 4. Average score for K-nearest Neighbor and Logistic Regression algorithm is 0.98 and 0.82, respectively.

From Table 4, we may conclude that Logistic Regression algorithm achieves the best accuracy level of 89% using the 80%:20% dataset ratio. Whereas, K-Nearest Neighbor algorithm achieves the best accuracy level of 96% using the 70%:30% dataset ratio.

4 CONCLUSIONS AND FUTURE WORK

Tuberculosis and Covid-19 have almost similar symptoms, so it is necessary to pay attention to avoid TB patients from Covid-19 infection. Experimental results showed that the accuracy of prediction analysis of Tuberculosis disease spreading pattern in Muara Enim District using KNN algorithm is higher than Logistic Regression. The best accuracy value using Logistic Regression algorithm is 89% while the best accuracy using K-Nearest Neighbor algorithm is 96%.This research provides useful insights regarding the spread of TB during the Covid-19 pandemic and the use of K-Nearest Neighbor algorithm as a reference for further research.

This research only compares KNN algorithm with Logistic Regression and does not consider existing works, as we use specific dataset. Thus, the authors consider other techniques such as Artificial Neural Network, Support Vector Machine, and Fuzzy inference to be implemented to analyze the dataset.

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REFERENCES

[1] Y. Arvita and D. Meisak. 2021. Information System for Collecting Data on People Affected by Tuberculosis for Covid-19, (in Bahasa Indonesia), J. Sains dan Inform., vol. 7, no. 2, pp. 202–211, 2021, doi: 10.34128/jsi.v7i2.344.

[2] H. Samudi, and S. Widodo, 2019. Comparison of the K-Nearest Neighbor and Naive Bayes algorithm in the treatment of warts using cryotheraphy), JUITA J. Inform., vol. 7, no. 2, pp. 93–99, 2019.

[3] R. Yunus, U. Ulfa, and M. D. Safitri. 2021. Application of the K-Nearest Neighbors (K-NN) algorithm for classification of heart failure, J. Appl. Intell. Syst., vol. 6, no. 1, pp. 1–9, 2021.

[4] A. G. B. Ganesh, A. Ganesh, C. Srinivas, Dhanraj, and K. Mensinkal. 2022. Logistic Regression technique for prediction of cardiovascular disease, Glob. Transitions Proc., vol. 3, no. April, pp. 127–130, 2022, doi: 10.1016/j.gltp.2022.04.008.

[5] M. Muhathir, T.T. Sibarani, & A. Al-Khowarizmi. 2020. Analysis K-Nearest Neighbors (KNN) in Identifying Tuberculosis Disease (TB) By Utilizing Hog Feature Extraction, Int. Comput. Sci. Inf. Technol. Journal, vol. 1, no. 1, pp. 33–38, 2020.

[6] S. Widaningsih. 2019. Comparison of Data Mining Methods for Predicting Values and Graduation Time of Informatics Engineering Students with C4.5, Naïve Bayes, Knn and Svm Algorithms, (in Bahasa Indonesia), J. Tekno Insentif, vol. 13, no. 1, pp. 16–25, 2019, doi: 10.36787/jti.v13i1.78.

[7] R. A. Rizal, N. O. Purba, L. A. Siregar, K. Sinaga, and N. Azizah. 2020. Analysis of Tuberculosis (TB) on X-ray image using SURF feature extraction and the K-Nearest Neighbor (KNN) classification method, JAICT, vol. 5, no. 2, pp. 9–12, 2020, doi: 10.32497/jaict.v5i2.

[8] M. I. Gunawan, D. Sugiarto, and I. Mardianto. 2020. Improved Performance of Diabetes Mellitus Prediction Accuracy Using the Grid Search Method on the Logistic Regression Algorithm, (in Bahasa Indonesia) J. Edukasi dan Penelit. Inform., vol. 6, no. 3, p. 280, 2020, doi: 10.26418/jp.v6i3.40718.

[9] A. Wulandari. 2020. Comparison of classification of stock price movements PT. Astra Internasional Tbk uses stationary vector auto regressive (var) and logistic regression, (in Bahasa Indonesia) eProceedings Eng., vol. 7, no. 1, pp. 2614–2626, 2020.

[10] Utami *et al.* 2021. Integration face recognition and body temperature, JITE, vol. 5, no. July, pp. 53–64, 2021.

[11] K. Kristiawan and A. Widjaja. 2021. Comparison of Machine Learning Algorithms in Assessing a Retail Store Location, (in Bahasa Indonesia), J. Tek. Inform. dan Sist. Inf., vol. 7, no. 1, pp. 35–46, 2021, doi: 10.28932/jutisi.v7i1.3182.

[12] D. Stiawan, S. M. Daely, A. Heryanto, N. Afifah, M. Y. Idris, and R. Budiarto. 2021. Ransomware detection based on opcode behaviour using k-nearest neighbours algorithm, Inf. Technol. Control, vol. 50, no. 3, pp. 495–506, 2021, doi: 10.5755/j01.itc.50.3.25816.

[13] J. He and X. Fan. 2019. Evaluating the performance of the K-fold cross-validation approach for model selection in growth mixture modeling, Struct. Equ. Model., vol. 26, no. 1, pp. 66–79, 2019, doi: 10.1080/10705511.2018.1500140.

[14] S. Saud, B. Jamil, Y. Upadhyay, and K. Irshad. 2020. Performance improvement of empirical models for estimation of global solar radiation in India: A k-fold cross-validation approach, Sustain. Energy Technol. Assessments, vol. 40, no. June, p. 100768, 2020, doi: 10.1016/j.seta.2020.100768.

[15] T. & I. Hutapea. 2018. Application of Modified K-Nearest Neighbor Algorithm in Classification of Schizophrenic Mental Illness, (in Bahasa Indonesia), J. Pengemb. Teknol. Inf. dan Ilmu Komput., vol. 2, no. 10, pp. 3957–3961, 2018.

[16] F. D. Pramakrisna, F. D. Adhinata, N. Annisa, and F. Tanjung. 2022. Web-based sms classification application using logistic regression algorithm, (in Bahasa Indonesia), TEKNIKA,vol. 11, no. 2, pp. 90–97, 2022, doi: 10.34148/teknika.v11i2.466.

Hand Detection and Hand Recognition Application Design for Human Computer Interaction Using SSD and Hand Landmark

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ABSTRACT

This research is intended to support computer interaction technology, especially the operation of computers to minimize the adverse effects of the dangers of direct physical contact between hands and technological objects. This research was conducted with the aim of utilizing the movement of the limbs of the hand as an object of interaction that bridges between humans and computers. With this research, it is hoped that the design results can minimize the risk of spreading bacteria and viruses that cause health problems. The objects used in the design will focus on the pattern/shape and movement of the hands, and in training the pattern/shape of the hand as a pointing tool and keyboard shortcut input. The design was built by using a webcam as a sensor to capture images. This design used the help of the field of artificial intelligence, hand detection using the Single-Shot Detector method with hand recognition using Hand Landmark. The value of success in functionality obtained from the application was 94.73%. The results of the model evaluation obtained that the final average recall value was 96%, the precision value was 100%, and the accuracy value was 96%. From the research that has been done, it is possible to replace the mouse function and several keyboard shortcuts with right- and left-hand movements.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI); HCI design and evaluation methods; Usability testing.**;

KEYWORDS

Hand Recognition, Artificial Intelligence, Single-Shot Detector, Hand Landmark, Human and Computer Interaction

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1 INTRODUCTION

One of the unfold of viruses and bacteria that has received the most attention is droplet transmission. This is sometimes a very worrying part about the emergence of an uncontrolled spread. Hong Kong University released data on the distribution of the influenza virus between several donors and recipients in the sample data for research. From the research that has been carried out, the largest virus distribution is from donors, namely our own hands that are in direct physical contact with the recipient's surface [1].

These results hence proved that the largest data of virus distribution comes from the main donor. The main donor in this case is our own hand which is in direct physical contact with the surface of the recipient object. Therefore, an effort is needed to anticipate and prevent the rapid spread of the virus. Efforts can be made such as reducing direct physical contact with objects that are used together. As for other efforts that we can do is to maintain personal hygiene, especially in the hand area.

There were several applications that support device control without making direct contact. However, from the research that has been done in this regard, this function was only limited to one hand in control and focuses on controlling certain input devices such as the mouse or keyboard only. So, from the needs of the existing problems, it is necessary to have an application that can support the two main input devices, namely the mouse and keyboard by using both hands in the recognition process. This will certainly make it easier for variations in the recognition of hand movements as an important form of output in terms of device control to create optimal human-computer interaction.

The objectives and outputs that the author put forward based on the background and existing problems are making applications that can recognize and detect the shape of the interacting hands to reduce direct physical contact with any computer device. The application can recognize hand movements and recognize every condition of the hand shape when interacting with the platform to facilitate the device access process. Another goal is that this application is expected to be a substitute for interaction between humans and computers. This is primarily concerned with controlling the mouse and keyboard.

2 RELATED WORKS

Virtual Mouse using hand gesture recognition based on Hand Landmark Model for pointing devices focused on making hand movements as Hand Recognition by using the Hand Landmark feature as

a substitute for pointing devices which focused on 4 main features for clicking, namely, left, right, double, and moving the cursor. The result had an accuracy rate of more than 90% and a failure percentage of less than 10%. In addition, there was several results from the testing with varying distance conditions with a recall rate of 96.5%, 100% precision percentage, 96.5% accuracy. The average time required for the system to detect hands was 0.05 seconds. Then the test with light settings got hand detection performed by the system on average 0.06 seconds with 95.8% recall, 100% precision percentage, and 95.8% accuracy [2].

VIMO Applications as Virtual Mouse with Real Time Gesture Recognition used programming from the VIMO application with the aim of controlling the movement of the mouse cursor with features of cursor movement control, left click, right click, scroll up, scroll down commands, as well as wink function for calibration user background. From the test results using a webcam with a sensor distance from an object between 60 cm to 200 cm, the test accuracy was 92.5% [3].

The design of a system regarding recognizing hand gesture considering interaction between computer and human in a reducing cost and maintain real time recognition in HCI by using a particular camera as sensor. The proposed design had the preference of cost reduction and high performance by counterfeit the occurrence of a computer mouse in several hand positions. Users could customize different features of the four gestures. For example, first motion was configured to click position. The physical implementation has been done in the embedded system. The demonstration results showed that the proposed design works in actual time and showed a great degree of accuracy in hand gesture recognition. The recognition rate of proposed method could reach 90% accuracy or higher. It was implemented in actual time conditions, the detection rate under some interferences was still above 83% [5].

Computer control in human-machine interaction systems by hand movements explored solutions for building hand tracking and gesture recognition systems that allow cursor movement and appropriate mouse and keyboard control by using an HD resolution webcam to obtain an image of the webcam hand continuously recording video at a constant speed. The image received from the webcam had to be processed first. The position of the mouse pointer was an important point of the hand. When this key point moves, the mouse pointer will move with it. When the finger moved (click, keyboard control), the key point will vibrate. With MediaPipe and Python Programming and other supporting libraries to extract key points from hand to computer mouse control. For example, cursor, left click, right click, double click, drag and drop operations. The results of this study had a 95% or more recognition rate compared to the color band method which was only 95% for cursor movement. The method used at least had a higher accuracy rate of 2.5% for cursor movement and for drag action it was 11% higher [7].

Based on all the related works showed the many uses of the CNN model in the research method, the Landmark model, and the combination of several models at once. To methodically use a lot of deep learning, TensorFlow and segmentation. While the used datasets mostly used the author's own development and there were several datasets that form a new model by comparing using previous models. For the evaluation results, it had measurements of accuracy in recognition rate, recall, and precision as well as various additional variables that were considered, such as background variations with the majority evaluation value was above 90%.

3 RESEARCH METHODOLOGY

From the research that has been carried out, following several steps carried out which was contained in the research stages as shown in Figure 1.

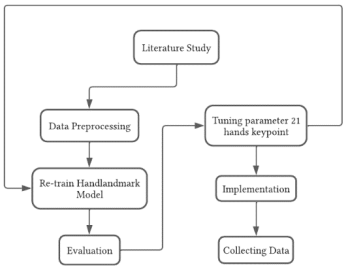

Figure 1: Research Stage Diagram

From the research that has been carried out, following several steps carried out which was contained in the research stages as shown in Figure 1. Preprocessing data was used in the training process, the hand movement images would be detected using the Single Shot Detector method to detect the shape of the hand as complete gesture. Development of the Hand Gesture Recognition Model from this predetermined dataset was using the Hand Landmark Model from MediaPipe which was implemented with the Python programming language and the MediaPipe machine learning framework. In the Retrain Hand Landmark Model, the recognized model would be rehearsed repeatedly for which key points appeared or not on certain Movements. Thus, forming a complete mapping of the evaluation and tuning process.

In the evaluation of the hand key point movement, an evaluation was carried out to show the suitability of the key point value that appeared from the dataset that has been set at the beginning to be carried out. If it was not appropriate from the evaluation results, then the tuning process will be carried out so that when the desired movement will be detected with the appropriate key point from the output Hand Landmark model. In the tuning process, parameter 21 hands key point performs an iterative process when key point data emerged from the model to adjust the existing dataset before proceeding to the implementation process. The data collection itself was based on testing with the distance parameter [2]. In this distance test, it served to determine whether the distance parameter would have a significant impact on the performance effect of the recognition of the hand movement.

In the Implementation section, after all the models have been finalized or recognized, mapping would be carried out with the event handler process which functions for the movement and condition of the mouse and then the shortcuts that would be used. For programming would use the Python programming language. The dataset that would be used was hand gestures with finger points 1 to 5, right fist. In both hands. The detection method that would be

used was a single-shot detector and hand recognition would use the Hand Landmark model from MediaPipe.

3.1 Datasets

The dataset illustration and feature mapping were shown in Table 1.

Table 1: Dataset Illustration and its mapping features

No	Movement	Variety of Recognized Left-Hand Movement		Variety of Recognized Right-Hand Movement	
		Illustration	Event Handler	Illustration	Event Handler
1	Open		Windows + Shift + S		Mouse move
2	Close/Fist		Windows + D		Mouse down kiri
3	1 Finger		Show Menu		Left click
4	2 Fingers Alternative		Ctrl + C		Double click
5	2 Fingers		Ctrl + V		Scroll up
6	3 Fingers Alternative		Windows Onscreen Keyboard		Scroll down
7	3 Fingers		Windows		Middle click
8	4 Fingers		Alt + F4		Mouse drop

3.2 Proposed Model

In this section, after all the final or recognized dataset models would be mapped with the event handler process, which functioned for the movement and condition of the mouse, then the shortcuts that would be used. For programming, we would use the Python programming language. The used dataset was hand movement with finger points 1 to 5, and fist hand movement in both hands. The detection method used is a single-shot detector and hand recognition will use the Hand Landmark Model from MediaPipe.

The SSD method originated from the concept of a feed-forward convolutional network that produces a bounded collection of boxes and their scores to represent object class instances on these boxes, followed by a non-maximum suppression step to produce the final detection. It added a convolutional layer feature at the end of the base network that has been truncated. This layer is progressively reduced in size and provides predictive detection at multiple scales [8].

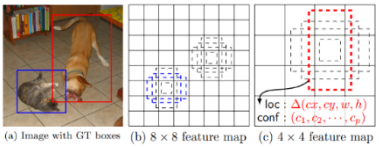

Figure 2: Frameworks in SSD. (left) Image with GT grid, (middle) 8x8 feature map, (right) 4 x 4 feature map. [8]

Figure 2 shows an illustration of how the Single-Shot Detector method works from getting input and interpreting it in the desired form. In the convolutional predictor feature for detection in each feature layer (or it can be in the existing layer on the base network) can produce a fixed set of detection predictions using a convolutional filter. Here's how the SSD works with its CNN feature:

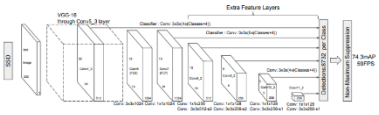

Figure 3: SSD Model with the addition of several feature layers. [8]

In Figure 3 shows the architecture of the detection model on the SSD. In a feature layer of size such as m × n with the number of channels p, the basic element for the parameter predicting a potential detection is the 3 × 3 × p small kernel which returns either a value for a category, or an offset form corresponding to the coordinate grid. at the beginning. At each location m x n where the kernel is applied, it will produce an output value. The bounded box offset output value is measured according to the relative box position at each feature mapping location.

In the training process of the SSD method, three tests are used with varying datasets for each process. The training process carried out in this method was the dataset from VOC 2007, VOC 2012, and COCO dataset [7] [8] [9]. From the three datasets used, various detection results were obtained using the SSD method with the addition of images data expansion. SSD 300 and SSD512 are SSD models with the latest augmented data. On the SSD512 model, the performance is significantly three times faster than PASCAL VOC and COCO in terms of accuracy. Meanwhile, the SSD 300 model can run at 59 frames per second, which is faster than the YOLO method [6].

3.3 Model Architecture

The key point data that emerges from the model was to adjust the existing dataset before continuing for the implementation process using the Hand Landmark model process from MediaPipe.

After the hand detection process was carried out, the Hand Landmark Model determined the coordinates of 21 knuckle points in 3D in the hand area detected through regression, namely direct coordinate prediction (Figure 4). The model will learn the representation of hand poses internally and can be seen robustly on the hands.

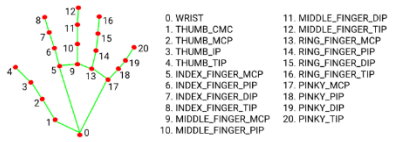

Figure 4: Hand Landmarks with its 21 Hand Key point. [Public Domain], via GitHub Google. (https://google.github.io/mediapipe/images/mobile/hand_landmarks.png)

The key point Landmarks used from each dataset that have been determined can be seen in Table 2 below:

Table 2: Key point Used from Hand Landmark Model

No.	Movement Name	Key point Landmark Model Code
1	Open	4, 8, 12, 16, 20
2	Close/Fist	4, 8, 12, 16, 20
3	1 Finger	variety of 4, 8, 12, 16, 20
4	2 Fingers Alternative	4 and Variety of 8, 12, 16, 20
5	2 Fingers	variety of 4, 8, 12, 16, 20
6	3 Fingers Alternative	4 and variety 8, 12, 16, 20
7	3 Fingers	variety of 4, 8, 12, 16, 20
8	4 Fingers	variety of 4, 8, 12, 16, 20

3.4 Evaluation Method

The data collection itself was based on testing with the distance parameter [2]. In this distance test, it served to determine whether the distance parameter will have a significant impact on the performance effect of the recognition of the hand movement. It also considered the level of selection of the distance parameter as one of the references in the evaluation function to determine the accuracy obtained which is quite optimal when the recognition process was carried out by the webcam camera in recognizing the object in front of it as an interaction. The next test carried out in data collection was to position the hand object in a certain area of the display. The initial image display resolution is 640 x 488 pixels. Then divided into 6 equal areas. The purpose of selecting a small output resolution is due to the limitation of the resolution of the device used which is intended to show the interaction of actions performed simultaneously using tools apss from third parties. The list of test scenarios using the distance parameter to be carried out can be seen in Table 3 below:

Table 3: Test Scenario with Variable Distance and Coordinate Area

Testing Variable		Sub Scenario	Number of tests conducted
Object Distance	Screen Display Coordinate		
		Open (Right)	3 times
		Close/Fist (Right)	3 times
1.5 m	1. 0,0 - 213,214	1 Finger (Right)	3 times
2 m	2. 214,0 - 427, 244	2. Fingers Alternative (Right)	3 times
3,5 m	3. 428,0 - 640, 244	2 Fingers (Right)	3 times
	0,245 - 213, 488	3 Alternate Fingers (Right)	3 times
	4. 214, 245 - 427, 488	3 Fingers (Right)	3 times
	5. 428,245 - 640, 488	4 Fingers (Right)	3 times
		Open (Left)	3 times
		Closed (Left)	3 times
		1 Finger (Left)	3 times
		2 Fingers Alternate (Left)	3 times
		2 Fingers (Left)	3 times
		3 Alternate Fingers (Left)	3 times
		3 Fingers (Left)	3 times
		4 Fingers (Left)	3 times

From the existing test plan, 3 times each with two main parameters, namely the distance parameters (3 x 16 x 3) were 144 times and screen application coordinates (6 x 16 x 3) were 288 times. So, it could be determined whether the test results are true or false with the following equation:

$$\text{Accuracy} = \frac{Total\ of\ correct\ classifications}{\text{Total of test data}} \times 100\% \quad (1)$$

$$\text{Speed} = \frac{\sum \frac{\left(\sum \frac{Total\ of\ test\ sub-test\ data}{Total\ of\ test\ sub-test\ data} \times 100\right)}{\text{Total of test sub-data}} \times 100}{Total\ of\ test\ data} \times 100\% \quad (2)$$

Furthermore, from the accuracy obtained then calculations were carried out to test the level of accuracy using the recall, accuracy, and precision methods using the Confusion Matrix. Confusion Matrix Method could be divided into 4 prediction totals: the sum of true negated prediction (True Negative), the sum of false positive prediction (False Positive), the sum of false negated prediction (False Negative), dan the sum of true positive prediction (True Positive). Based on the confusion matrix, the recall value (r), precision (p) could be calculated by the following equation:

$$r = \frac{TP}{TP + FN}, \quad p = \frac{TP}{TP + FP} \quad (3)$$

The final accuracy of the test obtained was by using the equation:

$$a = \frac{TP + TN}{TN + FP + FN + TP} \quad (4)$$

These equations would be used to conclude the output of data collection with the scenario of the distance parameters and the pixel area of the screen coordinates.

4 RESULTS AND DISCUSSION

The following was a display of the application when the system recognizes hand movements which were functioned as certain commands using the Event Handler function.

Figure 5: System View on Right Hand Recognition with Event Handler related to mouse control: (A) Move, (B) Left Click

In Figure 5 showed the Mouse Hover action, image recognition was done by recognizing the right hand. And then, the recognition was used to count the number of fingers that were being shown. In this condition the number of fingers used was 5 fingers or the same as an open hand. As for the coordinates of the movement of the mouse pointer itself, it related to the location of the right index finger. On mouse action left click used right hand gesture recognition by pointing only one finger shown. When the app recognized the movement of the right hand pointing a finger, it would recognize it as a left click action.

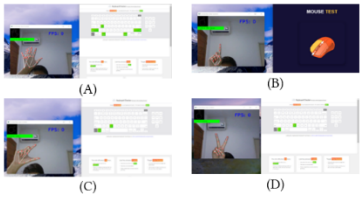

Figure 6: System Display on Left Hand Recognition with Event Handler related to Keyboard Shortcut: (A) Print screen (B) Show Menu, (C) Copy, (D) Paste

In Figure 6 showed the system display when the application recognized the left-hand movement for keyboard shortcut control. In this control the application recognized the movement of the left hand showing five fingers in total or forming an open hand. When the application recognized the movement of the hand that forms an open hand on the left hand, the application would recognize it as a form of a print screen command then the print screen command would be interpreted as a keyboard shortcut command to direct to the windows snipping tools application, namely with the shortcut "Windows + Shift + S". On the keyboard shortcut menu action was using left hand gesture recognition by showing only one finger is shown. When the app recognized a left-hand gesture pointing a finger, then the app recognized it as a shortcut menu action. Next from the keyboard control action process was to copy the shortcut or "Ctrl + C" action. In this control, the application recognized the left hand which is indicated by two fingers with the condition that one of the fingers shown was the thumb.

From the results of data collection carried out from the use of parameters, it could be determined the comparison value of each main scenario. The following was a comparison of the data results obtained using the distance and coordinate variable parameters.

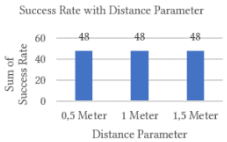

Figure 7: Comparison of Success Rate based on Distance Parameters

Figure 7 showed a comparison graph of success with distance parameters, it was found that success rates with different distance variations had the same success and accurately recognized hand movements. It could be seen from the total of all the tests that have been carried out using several conditions of the distance between the object and the camera, the success remained stable and precise.

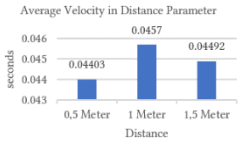

Figure 8: Comparison Velocity Rate based on Distance

In Figure 8 showed a graph of the speed comparison of each distance parameter. The average speed value of each transaction had a different significance. The fastest recognition speed was carried out with a distance parameter of 0.5 meters. The next fastest speed value after parameter 0.5 meters, followed by parameter 1.5. And finally, the 1-meter distance parameter occupied the longest average speed among the three parameters that have been carried out.

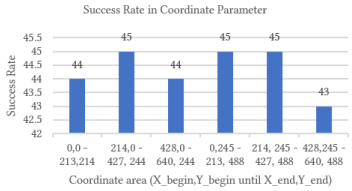

Figure 9: Comparison of Success Rate based on Coordinate Parameters

In Figure 9 showed a comparison graph of the highest success, which was 45 times successful. This is of course of lower value if you look at the comparison using the distance parameter (regardless of the coordinate position of the hand movement). From the results of the comparison with the coordinate parameters, the highest success values were obtained in the 2nd, 4th, 5th scenario areas. So, it could be noticed the optimal movement of the recognition that was carried out with a high success rate in the coordinate

area near the center area of the existing image display. Meanwhile, recognition performed with coordinates that were too late at the edges of the image display would have a lower recognition value and were less reliable in terms of the recognition process.

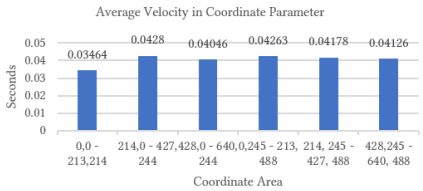

Figure 10: Comparison of Velocity Average based on Coordinate Parameters

And lastly, on the comparison of existing charts. It could be seen in Figure 10, the average speed value obtained was directly proportional to the success obtained in the recognition that had been carried out. Like the success rate, the average speed obtained with the highest and quite significant speed values was in the coordinates of the 2nd, 4th, and 5th scenarios. Based on the tests carried out with the two main parameters, namely the test with the distance and coordinates of the location of the hand area, the overall value was obtained in Table 4 below.

Table 4: System Evaluation Result

Test Parameters	Recall	Precision	Accuracy	Speed (s)
Distance Test	100%	100%	100%	0,044882
Coordinate Test	92,01%	100%	92,01%	0,04059
Total average	96%	100%	96%	0,042

From previous research references using the same method [2], the application design obtained had a recall value of 96.5% with 100% precision, and an average accuracy of 96.5%. Although from the results of the average comparisons carried out, there was insignificances differences found 0,5% decreased in terms of recall and accuracy, the precision is remained the same as the previous work. And regarding the Average Total Speed taken for testing by using the same parameter particularly distance test, it increased by 0,01 s. Also, in terms of functionality, the research that has been done had additional features related to recognition by distinguishing the recognition of right- and left-hand movements. While the previous research was limited and focused on only 1 part of the hand movement.

5 CONCLUSION

The conclusion that can be drawn from the research was that the system application could recognize both hands (right and left) in terms of functionality the application could work well. Right hand was used as mouse control interaction. While the left hand was intended as a keyboard shortcut control. Tests by considering the distance parameter variable that have been carried out had 100% accuracy, precision and recall values, respectively. The test by considering the variable parameter coordinates of the location of the hand crust with the image display had a final precision value of 100% and the recall value and accuracy of each were 92.01%. The overall precision value of testing all parameters was 100%. Meanwhile, the recall value and accuracy were 96% respectively.

Suggestions that can be taken from research as a form of system development in the future are the need for the ability to be able to recognize hand movements at the same time as another option. The next option is related to research on more accurate hand recognition processing, especially in coordinate areas that are difficult to reach. for more varied hand movements for disabled users as a form of continuous human and computer interaction.

REFERENCES

[1] Z. Nan and Y. Li, "Transmission of influenza A in a student office based on realistic person-to-person contact and surface touch behaviour," *International journal of environmental research and public health*, vol. 15, p. 1699, 2018.
[2] J. D. Asmoro, Virtual Mouse Menggunakan Hand Gesture Recognition Berbasis Hand Landmark Model Untuk Pointing Device, Surabaya: Universitas Islam Negeri Sunan Ampel, 2022.
[3] A. Lora and P. D. Arnesia, Vimo Applications as Virtual Mouse with Real Time, Depok: Seminar Nasional Teknologi Informasi dan Komunikasi STI&K (SeNTIK), 2020.
[4] T.-H. Tsai, C.-C. Huang and K.-L. Zhang, Design of hand gesture recognition system for human-computer interaction, Jung-Li: National Central University, 2019.
[5] H. T. Thang, D. V. Hoa and D. N. Tuan, "Computer control in human-machine interaction systems by hand movements," *Computer science and Control engineering*, pp. 42-48, 2021.
[6] W. Liu, D. Anguelov, D. Erhan, C. Szegedy, S. Reed, C.-Y. Fu and A. C. Berg, "SSD: Single Shot MultiBox Detector," in *Computer Vision - ECCV 2016*, Springer International Publishing, 2016, pp. 21-37.
[7] M. Everingham and J. Winn, "The PASCAL Visual Object Classes Challenge," 7 June 2007. [Online]. Available: http://host.robots.ox.ac.uk/pascal/VOC/voc2007/.
[8] M. Everingham and J. Winn, "The PASCAL Visual Object Classes Challenge," 18 May 2012. [Online]. Available: http://host.robots.ox.ac.uk/pascal/VOC/voc2012/.
[9] T.-Y. Lin, M. Maire, S. Belongie, L. Bourdev, R. Girshick, J. Hays, P. Perona, D. Ramanan, Z. C. Lawrence and P. Dollár, "Microsoft COCO: Common Objects in Context," *ArXiv.org*, 2014.

K-Means Clustering Approach to Determine Ore Type in Laterite Nickel Deposit

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ABSTRACT

Nickel demand will increase as the electric vehicle production plan increases in the years ahead. Nickel matte is an important raw material in producing the producing electric cars. The precision and speed with which the kind of laterite nickel ore is determined based on the olivine concentration are critical because it affects energy requirements and nickel recovery. The present challenge is that it takes a long time to obtain the Loss on Ignition (LoI) number, which will be used to calculate the olivine concentration. As a result, an alternate approach for determining the type of ore without going through the phases of assessing the LoI value is required. The k-means clustering method examined data from one of the blocks in the PT Vale Indonesia Tbk mining region. The K-Means method is used to cluster data from 9 chemical elements. The olivine group that will be produced as a result of this analysis is characterized by three scenarios: the first one is the olivine group using two clusters according to the present split of olivine groups, namely high olivine and low olivine. The second scenario employs three clusters: high olivine, medium olivine, and low olivine. The third scenario uses four clusters based on the elbow method and silhouette guidelines. According to the findings, the best number of clusters was two clusters. The level of accuracy for 2 clusters, when compared with the conventional method, achieved 97.9% for cluster 1 and 85.0% for cluster 2.

CCS CONCEPTS

• **Computing methodologies** → Machine learning; Learning paradigms; Unsupervised learning; Cluster analysis..

KEYWORDS

Clustering, LoI, Olivine, Ore Type

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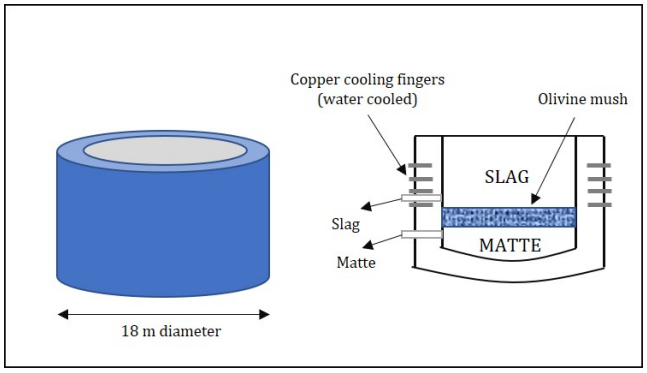

Figure 1: Profile of electric furnace

1 INTRODUCTION

Nickel is a metallic element created by nature named after the German term "Kupfernickel" in the 15th century. In general, nickel deposits worldwide are classified into two types: nickel sulfide and nickel laterite [1]. Nickel laterite is a weathered substance that forms on ultramafic rocks. Nickel ore is a mineral used to make nickel metal, which is used to make stainless steel, and nickel sulfate, the primary material used in electric vehicle batteries. PT Vale Indonesia Tbk is an Indonesian nickel laterite mining company that produces nickel matte as a final product using pyrometallurgical technology. Since the ore has a high olivine percentage, it takes high heat to melt, which will cause corrosion to the electric furnace. On the other hand, if the olivine content is too low, the nickel matte recovery will be lower. The profile of an electric furnace can be seen in Figure 1.

In the existing method, the olivine content is determined by petrography analysis or by calculating a formula based on the ratio of silica to magnesium and the amount of crystal water lost after burning at high temperatures, commonly known as Loss on Ignition (LoI). Based on the existing method, the olivine group is divided int 2 groups, namely high olivine (>22% olivine) and low olivine ($\leq$ 22% olivine). However, the current method has time and cost limits, hence a multi-method approach is required to determine the olivine content of drilling samples.

Based on the characteristics of data mining methods such as classification, association, clustering, regression, and forecasting, the clustering method is deemed the best suitable for the available data and the desired results. The K-Means method is one method in partial clustering analysis. Analysis of the value of k is an effective method since the cluster's outcomes rely on the precision with which the number of k is selected.

This research shows how to use k-means clustering to find the best cluster in the olivine content group. This K-Means cluster will also determine whether the existing method's separation of olivine groups is appropriate. The method described in this research can be applied to address the same problem in different nickel laterite mining areas, and it can be developed using other data mining methods.

2 LITERATURE REVIEW

Cluster analysis is a multivariate analysis that combines data or objects of observation into groups or clusters so that each group or cluster is homogeneous, and compact based on specific characteristics, and each group must be different [2]. K-Means clustering is a straightforward clustering algorithm that divides a dataset into k clusters. The primary basis of this method is to initialize k cluster centers (centroids) and assign data to the closest cluster based on the distance between objects. Based on the basic knowledge of the data being evaluated, the researcher can immediately determine the number of k. Aside from that, there are two ways of determining the number k: the Elbow and the Silhouette methods.

K-Means is a distance-based clustering method that divides data into a fixed number of clusters and functions only on numerical attributes. K-Means clustering uses distance metrics such as Euclidean distance, Manhattan distance, Euclidean distance squared, and Cosine distance. However, the Euclidean distance is the most commonly used. The implementation of this method is highlighted more in the process of grouping or clustering based on available data and the conclusions to be obtained.

K-Means clustering has often been used for data segmentation, such as in finance [3], disaster [4] and related to the segmentation of mining materials [5]. However, research on applying the K-Means clustering method in the nickel laterite industry is still rare. This study used the K-Means clustering method using Minitab software to classify laterite nickel ore types.

Laterite nickel processing technology is broadly classified into three methods: hydrometallurgical, pyrometallurgical, and selective reduction [6]. The chemical composition and mineralogy content of nickel laterite determine the effectiveness of mining and processing it with pyrometallurgical technology.

PT. Vale Indonesia Tbk is one of the Indonesian companies that applies pyrometallurgical technology to produce nickel in matte. In the pyrometallurgical processing to create nickel matte, olivine content is critical. Suppose the nickel ore being processed includes a high olivine percentage. In that case, it will perform as a heat transfer inhibitor to the matte, requiring elevated temperatures to melt it and potentially eroding the furnace. However, if the olivine content of the ore is lower, the matte-formed volume will be reduced because the bulk will dissolve in slag, which is a consequence of the processing. Currently, PT. Vale Indonesia determines the percentage of olivine using mathematical calculations based on a formula based on the ratio of silica to magnesia and LoI, with the requirement that the sample analyzed have a maximum iron percentage of 10%. %. If the olivine content value is below or equal to 22%, it will be grouped as low olivine; if the value is above 22%, it will be grouped as high olivine [1]. The presence of volatile substances (such as carbonates) or crystallized water that can be released at high temperatures is indicated by loss of ignition (LoI) [1]. It can also refer to relative mass loss after being heated over a brief period at a high temperature of roughly 750-960^0 C [7]. The LoI value may be used to estimate the serpentinization level of ultramafic rocks in magnesite mining by computing the LoI value from mined rock samples [8]. Laterite ores often include significant volumes of crystallization water, which must be eliminated throughout the nickel process. This water can be released at temperatures of up to 900^0 C.

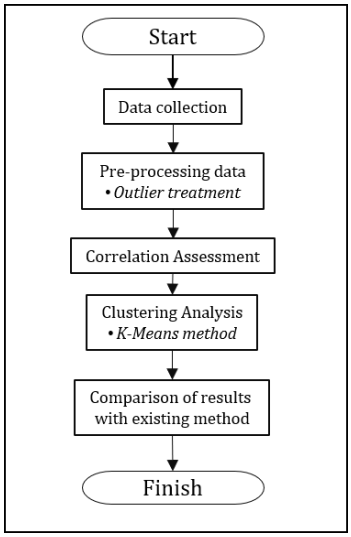

Figure 2: Flowchart of Research

3 METHODS

This research was performed at PTVI in Indonesia. The observations are restricted to data from the last five years (2015-2020). The bedrock zone with Fe 10% and MgO >30% content was chosen as the scope of observation for the coarse fraction drilling sample.

The methodology applied in this research included collecting drilling sample data (XRF analysis), pre-processing data with outlier treatment, choosing variables for clustering analysis using correlation evaluation, processing data with k-means clustering using Minitab, and comparing clustering results to grouping results using the present method. The steps in the research may be illustrated using the flow chart described in Figure 2.

The drilling data collection procedure collects data on the chemical content analysis of 9 elements from drilling samples in the form of percentage levels of nickel (Ni), iron (Fe), silica (SiO_2), magnesia (MgO), cobalt (Co), chromium (Cr), alumina (Al), manganese (Mn), and calcium (Ca), which will later be used in the data processing stage. The starting data utilized are 1000 data points that indicate a balanced composition of high olivine and low olivine groups according to the current method's categorization. Data pre-processing is a stage that removes outlier data to generate high-quality data. This procedure uses boxplot analysis to exclude outlier data based on statistical data distribution. Outlier data is data that is outside the box plot range.

To determine the relationship between variables, a correlation assessment was performed. This stage will choose the variables that will be subsequently processed for K-Means clustering analysis. Only the elements that are uncorrelated to weakly correlated are used in the following procedure (correlation value < 0.9) [9]. This stage is frequently referred to as the multicollinearity test.

The collected data will be clustered in this research using the K-Means technique and the Minitab software. The clustering process uses 3 scenarios. Scenario 1 divides the data into two clusters using k=2, similar to the present ore type group. Scenario 2 uses k=3, clustering the ore type into three groups. Scenario 3 uses the k value determined by the elbow technique and silhouette into four groups. Scenario 3 uses the k value determined by the elbow technique and silhouette.

Below are steps for k-means *clustering* with *K-Means* method [10]:

1. Determine the number of clusters k.
2. Determine the initial k cluster center (centroid). The most common initialization of centroid is determined randomly.
3. Place each object to the nearest cluster by calculating the object's distance to the centroid. To calculate the distance of all data to each cluster center, you can use the Euclidean distance with the following formula:

$$d(i,j) = \sqrt{(x_{1i} - x_{1j})^2 + (x_{2i} - x_{2j})^2 + \ldots + (x_{ki} - x_{kj})^2}$$

- d(i,j) = distance of data from i to cluster center of j
- x_{ki} = data to i on k attribute data
- x_{kj} = center point of j on k attribute

1. Recalculate cluster center with cluster members. The cluster center is the average of all data in a particular cluster.
2. Repeat steps 2 and 3 using the new cluster center. The clustering process is complete if the cluster center does not change.

The distribution of clusters in the form of a scatter plot is displayed to see the possibility of overlapping between clusters in the analysis of clustering results for each eventuality. The k-means clustering results and the effects of defining ore type groups using the current or conventional methods.

4 RESULTS

The study was carried out by gathering 1000 data sets from drilling results. These 1000 data points indicate a balanced mix of high and low olivine. Then move to the outlier treatment step, where boxplot analysis will be performed on all data variables that will be processed for the following stage. The following are the findings of a boxplot analysis performed on 9 chemical elements drilled with Minitab. All values outside the box and whisker plots, that is, values that are not within the range of the smallest observation value or minimum value and the most significant observation value or maximum value, are categorized as outlier data and are not utilized in the following step. According to boxplot analysis, the total data, including outlier data, is 258 data points, accounting for 25.8% of the total data. As a result, 742 data points, or 74.2% of the total data, will be used for the following stage. Figure 3 shows a boxplot of numerous chemical elements.

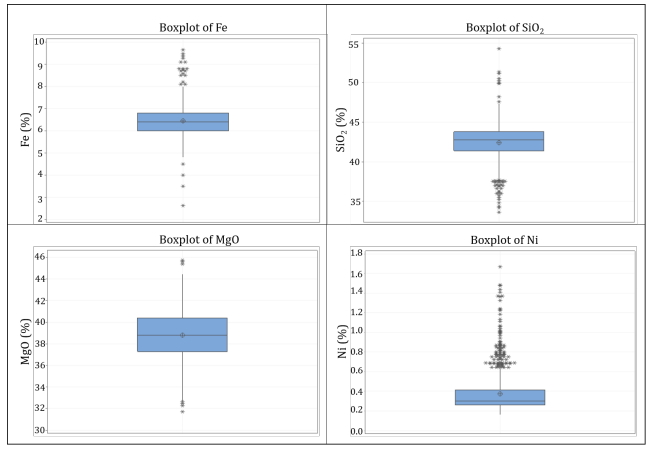

Figure 3: Boxplot analysis on chemical elements data

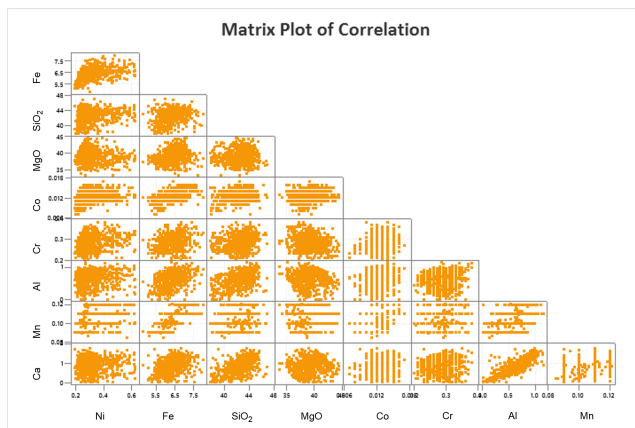

Figure 4: Correlation assessment of 9 elements of data

The variables arising from the outlier treatment selection were examined using the correlation method, specifically the Pearson correlation with a 95% confidence level, in the correlation evaluation. This test is also known as the multicollinearity test or the linear connection between independent variables. If the correlation matrix value between the two independent variables is 0.90, there is no multicollinearity. This correlation evaluation stage is done out with the Minitab 20 program, which uses the Stat > Basic Statistics > Correlation function. The correlation evaluation findings are depicted in Figure 4.

Based on the correlation evaluation results as can be seen in Table 1, there is no correlation matrix value more than 0.90, indicating no multicollinearity between variables and that the K-Means clustering analysis step may proceed.

Minitab was used to do the K-Means clustering analysis by selecting the Stat > Multivariate > Cluster K-Means feature. Three scenarios are considered in this clustering process for the number k. The first scenario uses k=2 to divide the data into two clusters, similar to the current ore type group. The second scenario employs

Table 1: Correlation value between variables

	Ni	Fe	SiO_2	MgO	Co	Cr	Al	Mn
Fe	0.450							
SiO_2	0.182	0.325						
MgO	-0.072	0.257	0.119					
Co	0.178	0.531	0.164	0.107				
Cr	0.271	0.250	0.243	-0.182	0.234			
Al	0.144	0.416	0.519	0.001	0.100	0.142		
Mn	0.314	0.778	0.370	0.212	0.493	0.184	0.470	
Ca	0.105	0.375	0.570	0.141	0.073	0.141	0.852	0.431

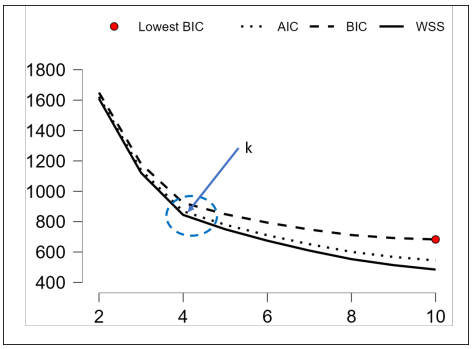

Figure 5: Determination of k value using Elbow method

K-Means Clustering

Clusters	N	R²	AIC	BIC	Silhouette
4	742	0.620	868.590	923.900	0.340

Note. The model is optimized with respect to the *silhouette* value.

Cluster Information

Cluster	1	2	3	4
Size	269	159	190	124
Explained proportion within-cluster heterogeneity	0.283	0.250	0.230	0.237
Within sum of squares	238.672	211.151	194.626	200.144
Silhouette score	0.399	0.299	0.304	0.311

Note. The Total Sum of Squares of the 4 cluster model is 2223

Figure 6: Cluster determination based on Silhouette score

k=3, aiming for the ore-type cluster findings to be classified as high, medium, or low olivine.

The third scenario uses the k value generated from the clustering process using the elbow method and silhouette. The Elbow method determines the number of clusters by looking for an angle where adding a data sample does not significantly impact the cluster membership. In the Silhouette method, the number of k is determined by the wide gap between each sample and all other samples in the same cluster or between other clusters. The higher the Silhouette score, the better the number of k is used. The elbow and silhouette methods were used in this research; the findings are shown in Figure 5 and Figure 6.

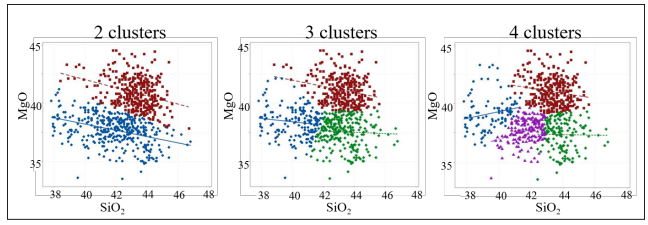

Figure 7: Scatter plot of K-Means clustering analysis

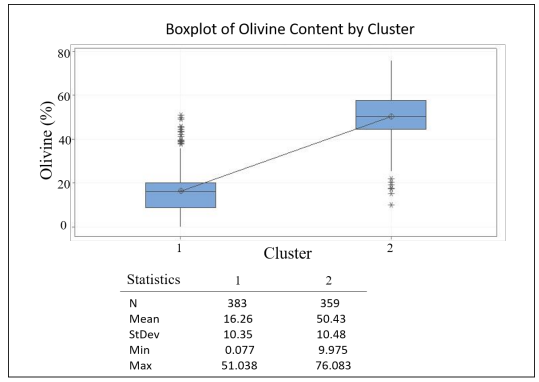

Figure 8: Boxplot analysis of cluster type comparison to olivine content for 2 clusters

Based on these two analyses, the optimal k value is 4 for the third scenario.

In the following stage, k-means clustering results using Minitab are shown in a scatter plot by comparing two chemical elements in each type of cluster. The x-axis value for the scatter plot is SiO2, and the y-axis value is MgO. Figure 7 shows the results derived from the K-Means clustering analysis for each scenario.

To compare the clustering results of each k value with the olivine content value in the initial data, the clustering results of each k value were compared using standard grouping methods. The boxplots presented in the figures below are used for the comparison. The x-axis is the olivine content based on initial data while the y-axis is the cluster type based on k-means clustering.

Figure 8 shows no substantial overlap between the olivine content values in Cluster 1 (low olivine) and Cluster 2 (high olivine). At 3 clusters, the olivine value in cluster 2 differs from clusters 1 and 3, although clusters 1 and 3 have a significant-considerable overlap (Figure 9). Furthermore, for 4 clusters (Figure 10), only cluster 2 shows a significant difference in high olivine values, whereas clusters 1, 3, and 4 exhibits significant overlap, making it difficult to differentiate the groups. The comparison of the olivine clusters from the k-means results to the current method is shown in the Table 2, Table 3 and Table 4.

The calculations and comparisons with current methods for cluster 1 show that the olivine content group is suitable for roughly 97.9 percent or 321 observational data from a total of 328 data. Cluster 2 had group conformity of 85.0%, or 352 observations out of a total of 414 observational data. In cluster 2, the difference is still approximately 15.0%. This disparity is evident in drilling

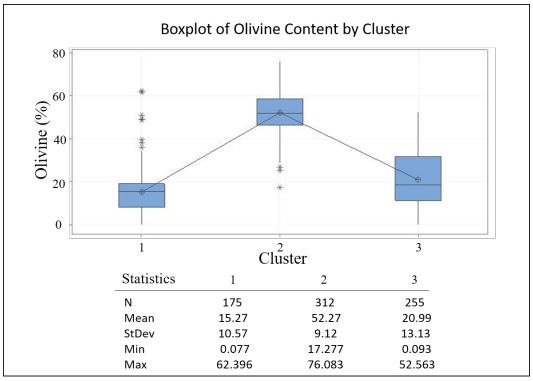

Figure 9: Boxplot analysis of cluster type comparison to olivine content for 3 clusters

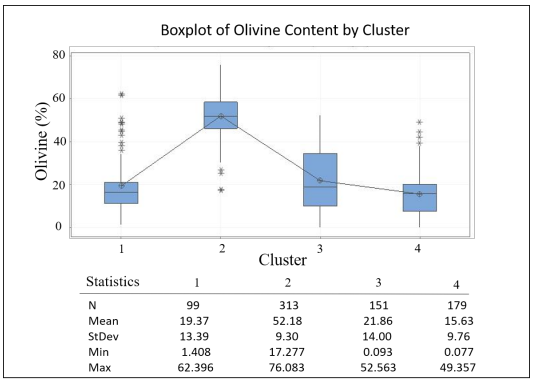

Figure 10: Boxplot analysis of cluster type comparison to olivine content for 4 clusters

Table 2: Comparison of K-Means clustering to current method for 2 clusters

K-means result	Current Method	
	Low Olivine (LO)	High Olivine (HO)
Cluster 1 (LO)	321	62
Cluster 2 (HO)	7	352
Total of Data	328	414
% of accuracy	**97.9%**	**85.0%**

samples with high silica and magnesia content, which geologically are rocks with a lot of olivine but are placed into low olivine clusters according to the clustering results.

5 CONCLUSION

The K-Means clustering method has been used to classify the olivine content used in determining the type of laterite nickel ore. Three scenarios of k values have been applied in the k-means clustering test. Based on each scenario, scenario 1 with a value of k=2 becomes the scenario with the best clustering results. With a value of k=2, the level of accuracy of the clustering results to the current method is higher when compared to the scenarios of k=3 and k=4. In scenarios k=3 and k=4, the level of overlap between clusters is quite large, so the level of conformity with the existing method is lower. This fact indicates that the division of olivine content groups applied by PT Vale Indonesia Tbk at this time divides the olivine content into 2 clusters, namely the high olivine cluster and the low olivine cluster, is similar to the results of the k-means clustering analysis. The comparison between the k-means clustering and the existing method showed an accuracy level of 97.9% for cluster 1 (321 observations from a total of 328 observations) and 85.0% for cluster 2 (352 observations from 414 observations). Based on this level of accuracy, the clustering method can be used as a substitute for the existing method in quickly determining the type of laterite nickel ore based on olivine content, especially for laterite nickel ore types have low olivine content groups. If the K-Means clustering method is applied to samples grouped as high in olivine, it will result in a more significant bias. In this case, the bias percentage reaches 15%. Therefore, for high olivine content, in addition to applying the K-Means clustering method, conventional grouping is still needed. The selection of rock samples free from the silica zone also affects the determination of the olivine content group. The advantage of this k-means clustering approach for companies is that the process of deciding olivine groups will be more efficient for companies both of this k-means clustering approaches because the process of

Table 3: Comparison of K-Means clustering to current method for 3 clusters

K-means result	Current Method		
	Low Olivine (LO)	Medium Olivine (MO)	High Olivine (HO)
Cluster 1 (LO)	84	73	18
Cluster 2 (HO)	0	1	311
Cluster 3 (MO)	83	87	85
Total of Data	167	161	414
% of accuracy	**50.3%**	**54.0%**	**75.1%**

Table 4: Comparison of K-Means clustering to current method for 4 clusters

K-means result	Current Method			
	Low Olivine (LO)	Medium Olivine (Mo)	High Olivine (HO)	Very High Olivine (VHO)
Cluster 1 (MO)	38	40	7	14
Cluster 2 (VHO)	0	2	9	302
Cluster 3 (HO)	50	48	16	37
Cluster 4 (LO)	79	71	23	6
Total of Data	167	161	55	359
% of accuracy	**47.3%**	**24.8%**	**29.1%**	**84.1%**

determining olivine groups will be more efficient for companies in terms of time and cost.

However, this k-means clustering approach has some limitations. Because this approach is unsupervised learning, it cannot predict clustering for new data. Therefore, the application of other data mining is needed to continue the results of this study. One of the data mining methods that can be done is the classification method so that new drilling data can be classified in the low olivine or high olivine group.

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REFERENCES

[1] Ahmad, W. 2006. Laterites: Fundamental of Chemistry, Mineralogy, Weathering Process and Laterite Formation. Sorowako

[2] Sharma, S. 1996. *Applied Multivariate Techniques.* John Wiley & Sons, Inc., New York

[3] Sukmadewanti, I., Arifudin, R., & sugiharti, E. 2018. *Use of K-Means Clustering and Analytical Methods Hierarchy Process in Determining the Type of MSME Financing in Semarang City.* Scientific Journal of Informatics. Vol. 5, No. 2, DOI: http://journal.unnes.ac.id/nju/index.php/sji.

[4] Liao, Q.Z., Xue, L., Lei, G., Liu, X., Sun, S.Y., & Patil, S. 2021. *Statistical prediction of waterflooding performance by K-means clustering and empirical modeling.* Journal Pre-proof, DOI: https://doi.org/10.1016/j.petsci.2021.12.032

[5] Jansson, N.F., Allen, R.L, Skogsmo, G., & Tavakoli, S. 2021. Principal component analysis and K-means clustering as tools during exploration for Zn skarn deposits and industrial carbonates, Sala area, Sweden. Journal of Geochemical Exploration, DOI: https://doi.org/10.1016/j.gexplo.2021.106909

[6] Bahfie, F., Manaf, A., Astuti, W., Nurjaman, F., *Herlina, U. 2021. Tinjauan Teknologi Proses Ekstraksi Bijih Nikel Laterit: Review on Technology of Nickel Laterite Extraction.* Jurnal Teknologi Mineral dan Batubara, Vol. 17, No. 3, 135-152, DOI: https://doi.org/10.30556/jtmb.Vol17.No3.2021.1156</bib>

[7] Vandenberghe, R.E., de Resende, V.G., da Costa, G.M., De Grave, E. 2010. *Study of loss-on-ignition anomalies found in ashes from combustion of iron-rich coal.* Fuel 89, 2405-2410, DOI: https://doi.org/10.1016/j.fuel.2010.01.022

[8] Pagona, E., Tzamos, E., Simeonidis, K., Zouboulis, A., Mitrakas, M. 2019. *Characterization and evaluation of magnesite ore mining procedures by-products from Gerakini mines, Chalkidiki, Greece.* EPAnEK.

[9] Ghozali, I. 2016. *Aplikasi Analisis Multivariate dengan Program IBM SPSS 21.* Badan Penerbit Universitas Diponegoro, Semarang

[10] Eldo, H. 2020. *Penentuan Cluster Terbaik K-Means Menggunakan Algoritma Silhoutte.* Tesis Magister, Universitas Sumatera Utara, Medan

DESIGN AN AGILE OF MACHINE LEARNING TO PREDICTIVE HOUSE PRICING AND TARGETING SEGMENTED MARKET

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ABSTRACT

Because of too high expectations or having a wrongly segmented target market, the developer hasn't received a good response from the target market. Developers need a new marketing tool that is based on data. The use of machine learning systems as marketing tools to help solve the problems in house price prediction is an important topic in the real estate industry. The design of machine learning will use CRISP-DM as a framework and to analyze using linear regression and random forest as the best possible accuracy. Besides that, to find a potential market, we will use K-Means as a clustering method. The modeling and experiments to design a machine learning engine that can predict a range of selling prices using linear regression can give maximum accuracy and analyze the target market. The research focusing on different attributes will bring different dominant attributes to the table too.

CCS CONCEPTS

• **Machine Learning**; • **Predictive Data Science**; • **Data Analytics**;

KEYWORDS

Agile, data analytics, data science, influence factor, house development market, linear regression, machine learning, predictive pricing, random forest, target market

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1 INTRODUCTION

The real estate company's business has focused on developing housing and commercial buildings for the lower-middle, middle and upper-middle market segments. The increase in business is in line with the increase in public demand for safe, comfortable and strategic housing, along with an increase in solid management experience and expertise in managing the company's business. The companies will supply some of the various residential projects with different target segmentation, from low to high segmentation, even while in the same project location. After more than 30 years of experience in city development, within the competitive showcase, information mining will donate an insight for administration to assist discover the profile of clients and discover their inclination, and selecting the modern item advancement fitting with their inclination [1].

This research will help real estate to have some predictions and the company will be able to decide a strategy how to penetrate to correct targeted market and will return good sales performance. Many real estate companies did some research in the beginning while they want to open a new project in the area. The companies realize some influence factors of housing will correlate with the performance of sales. The main goal of this research is to design powerful machine learning tools to give advice price prediction based on the most influencing factors for some potential buyers by a range of age. The machine learning tool could be used by property developers, house agents and customers/buyers. We realized, currently the big portion of housing buyers are in the millennial ages, that is why real estate companies release new products for them. This research also examines the most influential attributes reason to that various age when interesting to buy a new landed house. With the many influences attributes factor, every company needs to prepare the "*Agile*" situation to make competitive with the other real estate company competitors. The agility might be coming from internal or external factors.

In a rapidly evolving information technology field and business complexity, many organizations in the world have decided to start Digital Transformation, one of the IT digital transformations is Business Intelligence (BI) data analytics methods. The traditional BI is built and implemented as a set of concepts and methods to bring improvement and enhanced features to business decision-makers based on actual-transaction-based support systems [2]. This solution will process the history data and visualize it in the dashboards. Perhaps this IT solution is valuable to help the decision-makers make fast and better decisions because the strategy to become more agile to keep the organization more competitive in the fast-changing business and digital era.

The fastest-growing trend of *Machine Learning* has become the main application tool as a prediction approach in every sector. This research will be focusing on the prediction range of house pricing more accurately based on most influence attribute factors in the specific location, besides the historical actual sales data from the last few years. Many researchers are interested to be involved in this area, and many algorithms are evolving to implement *Machine*

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Learning. As property developers and customers (especially our typical investor customers), perhaps their house values increase significantly every year, which means they need modeling to forecast increasing house prices. This predictive modeling will be required as a parameter to find affordable pricing [3]. Besides the forecasting price, machine learning is also possible to learn and suggest a selected target market as a primary potential buyer.

In any business, it will be necessary to have the ability to find and learn what products or services are for their loyal customer needs. Perhaps will have some new points to leverage to search target market customers and bring different customized commercial programs for segmented customers. Machine learning is able to adapt to current situations which are suitable to their specific market segmentation in preference to doing a feasibility study that is quite often not an efficient result especially while having a large segmented market [4].

1.1 Research Problem

Customers are very selective during choosing a landed house. Many consideration and attributes influences before choosing a product. Usually, the real estate company will gather the first buyer product or investors buyer. The problem comes when there are many external factors variables that may influence the house price. The stakeholders including customers and property developers would like to identify the most affected influence attributes in the house pricing to help property companies be able to set the affordable selling price [5].

This research will help real estate companies find some research problems. Here is the research problem:

- Developers are need to identify the most attribute factors which influencing pricing
- Developer are need to identify the correct segmented target market. Since developer having a various typical buyer such as investor or end user.

By this research, new product housing can be proposed based on the correct customer profile, and then the marketing program can target the market to achieve company value maximally, also reduce promotion cost since the market is already predicted.

The main research objective is to predict house pricing and to predict a suitable target market, the point of view from Real Estate Company. And to finding and analyzing the market customer profile (segmented market), considering once a company needs to expand business in the new location or launch a new house product. The purpose of this study is to design agile predictive machine learning, with answering some research questions:

#1: While selling a house product, what are the attribute factors influencing a house's pricing? Then real estate can have sales predictions that are more accurate.

#2: Which segmented target market related the product with having the most attribute factors?

Perhaps this question will answer the suitable products that look like customer profiles needs. It might be helping the company too while opening new projects in the new area population and to do some commercial promotion correctly.

In this research, here are some of hypothesis:

#1: The most dominant attribute factors influencing is pricing, location and design.

#2: The potential segmented market is millennial (25-35) ages and having a budget spending between 500 million and 800 million rupiah.

2 LITERATURE REVIEW

According to some previous research papers, many influence factors will be affected directly in the house pricing. The factors are location, house design, land of ownership, property developer name, total land square meters, public facilities, public transport, and economic condition. This research, will identify and find the most influential factors that affected the house pricing, based on the previous history data and a potential customer expectation (based on survey). Each market segment will have attributes preferences/influences while needing to choose a landed house. The attributes such as location, ease of access, affordable price, design, and material quality, public facility, home design, property developer, the status of land ownership, and environmental aspects. The conclusion from the literature, the eight factors are indicators for potential buyers to decide before buying a new landed house [5]. The value itself is difficult to measure due to their variant product and due to a large number of transactions, sometimes the product does not represent the current market. The problem occurs because developers and their customers have different perspectives [5].

The new house product perhaps could be suitable with customer needs and customer profiles (low class, medium or high class), and while the buyer is living in their house, the economic value in the surrounding area will be growth. Affected by the situation, the value investment of property also grows in the next couple years. However, property companies are facing a common problem, once the house product can not be accepted by the market, the main cause could be from internal or external factors.

Machine learning is one of the modern computerized techniques for identifying, interpreting, and analyzing complex data structures and patterns [6]. Machine learning research is a part of artificial intelligence (AI) algorithm that attempts to train computers with new knowledge through data input. Machine learning, according to [7], is "*the science of getting computers to learn and act like humans do, and improving their learning over time in an autonomous fashion, by feeding them data and information in the form of observations and real-world interactions*".

In this research, the purpose is to design supervised learning techniques only. The prediction outcomes come from their historical data collection and some business considerations/business strategy and usage of a modern statistical model. The modeling focusing on forecasting sales revenue trends refers to the problems in current situations and future situations [8]. The predictive modeling will calculate the influence of the attributes from potential buyers as a variable factor. Meanwhile in this research, only focuses on these cases:

- Price Prediction Forecasting
- Segmented Market customer profile [9]

Predictive analytics method based on machine learning, building algorithms that extract and combine knowledge from existing data to determine the future. The same algorithm can be divided into two

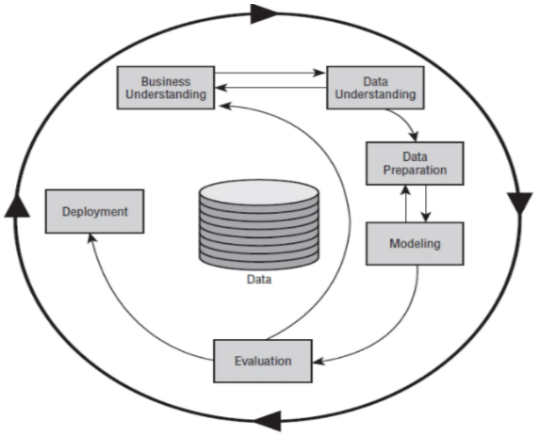

Figure 1: CRISP-DM Framework

main categories: unsupervised learning and supervised learning. This study uses a combination of supervised learning. Typically done in the context of pricing classification (characteristics) when mapping inputs to output labels, regression analysis when mapping inputs to continuous outputs and unsupervised learning methods segmented. Target market forecast [10]. This research, will be focusing on three predictive methods such as linear regression, decision tree, random forest and K-Means.

In data science, especially for Big Data Analytics (BDA) development, the development phase is to adopt an agile methodology. This method is also suitable for implementing agility in machine learning development systems [11]. The agile features methodology will bring to next-level projects in data science development cycles. While adopting the agile methodology approach, will bring machine learning to the next level of modeling tools [12].

3 RESEARCH METHODOLOGY

The research will be using quantitative and qualitative data to find the most attributed influence factor. The qualitative data will be used in the online & offline form surveys to gather what kind product of customer needs/expectations while looking for a new house and to know the customer satisfaction of the product in the specific location. The responders are all of walk-in guest and from previous buyers. The quantitative data will use sample historical data for the last few years. About the target market of sales, mostly for millennials, besides young family age and over 50 years old family. These data will be used to analyze and to process going to predictive data analytics.

Once get the collection of data to be analyzed using the statistical application tool through several stages of analysis, including assumptions that are proven through construction validity testing, reliability testing, multiple correlation testing, and linear regression analysis [13]. The final step is regression analysis to prove the hypothesis framework made. The research framework will use the *CRISP-DM* [14] methodology, the detail of research flows described in Figure 1.

Step 1: Business Understanding

In figure 2 the complete business understanding details flows.

Step 2: Data Understanding

In figure 3 the complete data understanding details flows.

Step 3: Data Preparation

The data preparation phase contains all the activities to create the final dataset from the first raw (initial) data. The important steps in this phase is data cleansing process, which is to ignoring *"garbage in"* will produce *"garbage out"*.

In figure 4 the complete data preparation details flows.

Step 4: Modelling

In this phase, various modeling techniques are selected and applied, and their parameters are adjusted to optimal values. During this phase, it is possible to roll back to the previous phase data preparation, to find the correct dataset. Machine learning will use regression and random forest as data analytic modeling. Regression

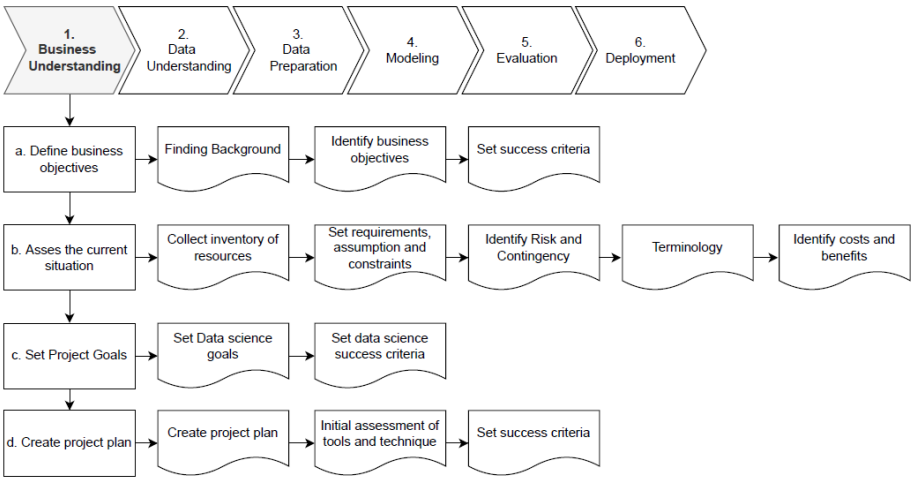

Figure 2: Business Understanding Details Flow

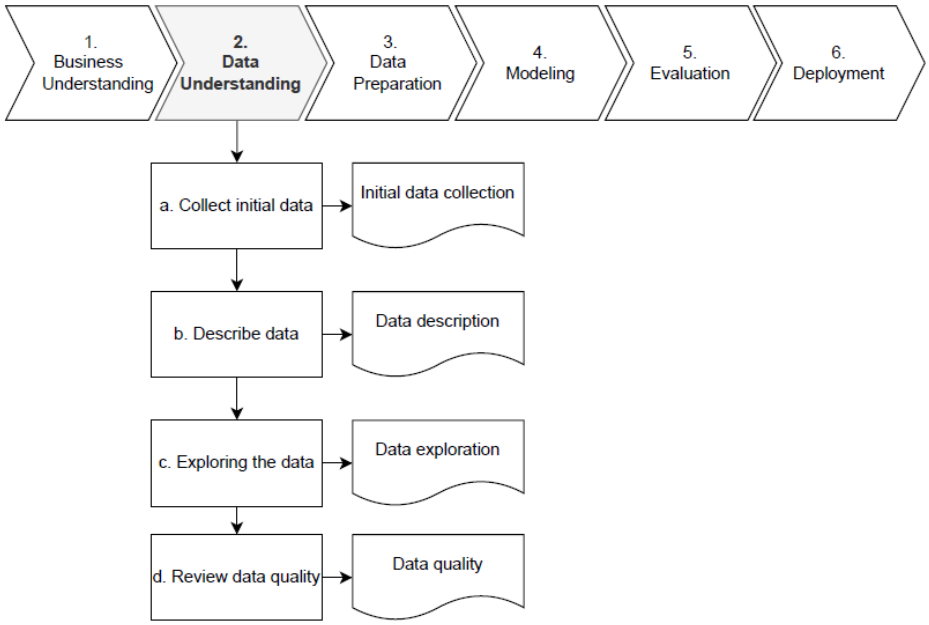

Figure 3: Data Understanding Details Flow

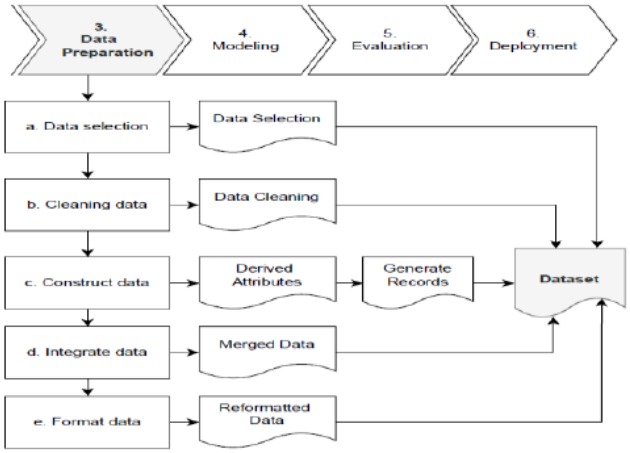

Figure 4: Data Preparation Details Flow

analysis is a reliable way to identify variables that affect a topic of interest. The regression process ensures that you can decide which factors are most important to you, which factors can be ignored and how these factors affect each other. The modeling will use Weka 3.8.5 as the data analytic tool. From some literature, the Weka application is a useful tool during analyst data mining and machine learning.

In figure 5 the complete modeling details flows.

Step 5: Evaluation

In this phase, evaluate the model that you receive more thoroughly and review the steps you used to build the model to ensure that your business goals are properly achieved. The evaluation starts from assessment the modeling result and proving the models is valid. The process review from beginning, to determine the next process could be continue or not. In figure 6 the complete evaluation details flows.

Step 6: Deployment

The purpose of this phase is create deployment plan, how to monitoring and maintain the modeling is to increase knowledge of

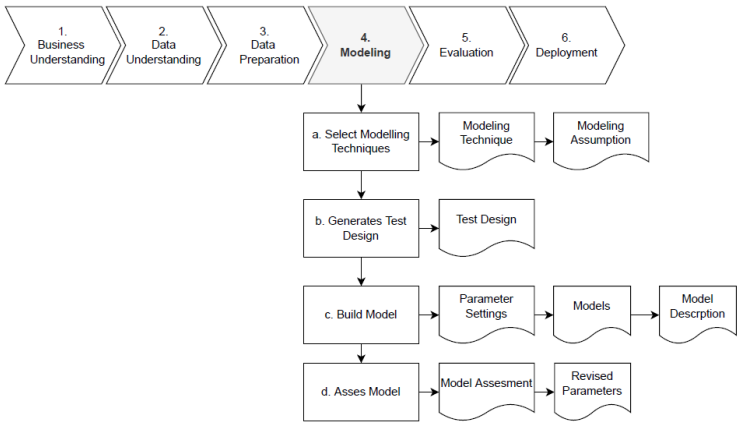

Figure 5: Modeling Details Flow

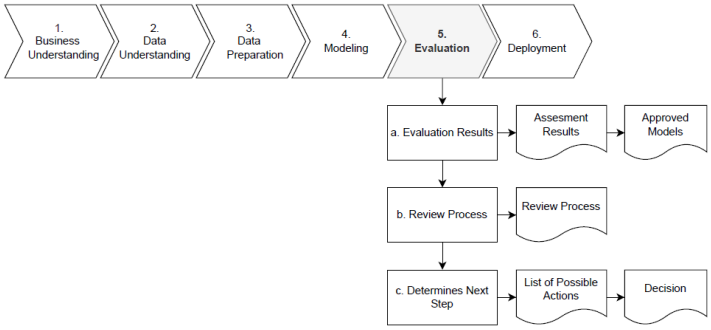

Figure 6: Evaluation Details Flow

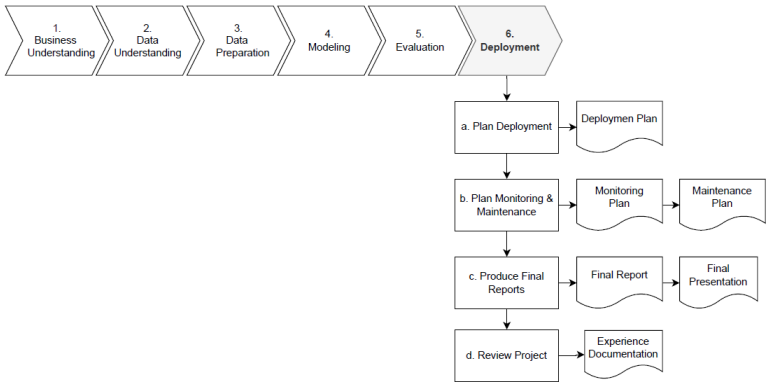

Figure 7: Deployment Details Flow

the data and provide a final report to answer to what the business needs in the first step and the last is to review the whole project again. As part of reports, a result of machine learning can be graphical visualization to represent the results in a way that is useful and understandable to their users (user friendly), and in order to achieve this, the machine learning project must achieve its main objectives.

In figure 7 the complete deployment details flows.

4 RESULT AND CONCLUSION

4.1 Result

The main and first step is to identify business understanding in the table 1:

Data understanding is the purpose of knowing what can be expected and achieved from data in the table 2.

Table 1: Business Understanding Result

No	Tasks	Results
1.	Define Business Objectives	
	a. Background	• Launching a new product is costly • Digital marketing is expensive • A new product is not acceptable by market (pricing issue, design issue, location, payment method, government policy etc)
	b. Business objective	Business needs a market predictions to get valid forecasting, and also to identify the mapping of potential target market
	c. Success criteria	The target market is accepted while the new house product and commercial promotion is effective & efficient comparing to cost expensed.
2.	Assess the current situation	
	a. Collect inventory of resources	• Man power: none data experts • Information: raw data from starting project, create data warehouse, create automatic update data • Software: need data mining tools, machine learning tools • Infrastructure: cloud services & internet connection 24/7
	b. Set requirements, assumption, constraints	• Requirement: Q1 2022 • Assumption: machine learning quality is > 55% of validity • •Constraints: initial projects, limited time, no machine learning experience,
	c. Identify risk & contingency	• Risks: need hiring the engineer, raw data not valid, raw data is not enough to cover information. • Contingency: outsource team engineer, spending time to adjusting the raw data
	d. Terminology	• Business: the most influence factors, statistic method, classification and clustering • Data science: process data mining, preprocessing, machine learning process, final result
	e. Costs and benefits	• Costs: cloud server, man power, machine learning tools • Benefits: increase sales revenue, effective marketing promotions
3.	Set project goal	
	a. Set data science goals	Valid predictions (>55%)
	b. Set success criteria	Increase sales revenue >20% and reduce marketing promotion <20%
4.	Project plan	
	a. Create Project plan	a. Discussion with business team b. Hiring engineer c. Summary business needs d. Analysis & design project machine learning e. Implementation & deployment f. Trial project g. Evaluation project
	h. Initial assessment of tools and technique	a. Data mining tools: Rapid Miner b. Data analytics tools: Weka c. Technique: linear regression analysis and random forest
	i. Set success criteria	Project on time in Q2 2022

Table 2: Data Understanding Result

No	Tasks	Results
1.	Collect initial data	Raw data from historical sales 20 years, contains: 1. Customer data 2. Sales data (price / payment method) 3. Detail house unit Raw data from survey data, contains: 1. Data respondents 2. Budget & payment method 3. Customer preferences (design/quality/product sizing)
2.	Describe data	1. Raw data historical has many typo, inconsistency data, range of price is wide 2. Raw data historical, range of house sizing is wide
3.	Exploring data	1. Historical: price, house sizing, age, occupation, payment method, city, address, type of unit, details unit location 2. Survey: budget, age, city, working location, customer needs, customer preferences
4.	Review data quality	Historical: inconsistent, typo, invalid data Survey: data offline survey has not completed fields

Table 3: Data Preparation Result

No	Tasks	Results
1.	Data selection	Historical data: 5000 records Survey data: 258 records
2.	Cleaning data	Some tasks in this step: •Remove extra spaces/null/duplicate •Convert text numeric data to numeric •Correction the wrong entry data •Convert text to various case •Check spelling •Normalize the wide gap value: o Price: low – med1 – med2 – high o Land: small – med1 – med2 - big
3.	Construct data	Grouping fields into a new columns
4.	Integrate data	Merging some data
5.	Format data	Create a data type (ordinal/numeric)

This phase is a planning to prepare and collect the sample of data in the table 3.

The next step is modelling using Weka tools. The analytics will be running to two datasets, the sampling historical and the survey dataset.

Sampling Historical Dataset:

- Linear Regression Result

With parameter test:
Attribute target: Price_01
Search Attribute Method: M5
Function: Cross-Validation with 10 folds

From some trials in this method, we have found the "Price_01" attribute with the highest correlation coefficient (0.9986) and RMSE values is 0.0278.

```
=== Cross-validation ===
=== Summary ===
Correlation coefficient                  0.9986
Mean absolute error                      0.0016
Root mean squared error                  0.0278
Relative absolute error                  0.3283 %
Root relative squared error              5.224  %
Total Number of Instances                5187
```

Figure 8: Linear Regression Test

- Random Forest

With parameter test:
Attribute target: Price_01
Function: Cross-Validation with 10 folds

From some trials in this method, we have found the "Price_01" attribute with the highest correlation coefficient (0.9934) and RMSE (0.062).

The detailed result test is in Figure 9.

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.9934
Mean absolute error	0.0104
Root mean squared error	0.062
Relative absolute error	2.1323 %
Root relative squared error	11.6576 %
Total Number of Instances	5187

Figure 9: Random Forest Test

During experiments, it would be use all of attributes factors as attributes of target, then the highest correlation coefficient value to identify the most influence factors from current dataset.

The result from data analytics can answer and proving the question research in the beginning:

#1: While selling a house product, what are the attribute factors influencing a house's pricing?

According to the current survey dataset, while focusing on the attribute budget medium (> 500 million-800 million), some attribute factors, such as design quality, payment method, house concept, and land square meters, are dominant. The different dominant factors might be different while focusing on the other attributes such as land area or location. The most influential attributes will be revealed by the large amount of survey data.

#2: Which segmented target market related the product with having the most attribute factors?

Refer to clustering analysis from the historical dataset, where cluster "1" has a higher percentage with sample attributes price_02 (medium low budget), land square meters needed is medium (> 50m2- 90m^2) and the buyer age is around 48 years old. Although compared to the survey dataset, the similar profiles in the cluster "0" have 36% of respondents. Then, these profiles are highly likely as segmented target markets.

4.2 Discussion

From this historical data and some new experiments, we can compare the most influential factors in that particular period. However, we need more experiments to find the probability periods when the expectations of potential buyers change. Perhaps machine learning can be designed to handle this case.

4.3 Conclusion

Based on some experiments in the data analytics methods, the Random Forest method has a higher accuracy value than the linear regression algorithm to find and seek the most influenced factors. Besides that, to find and identify the segments could be the K-Means method. Perhaps as a result of this research, we will be able to continue the design of machine learning and implement it in a real-world business case, and the machine learning will continue to learn with additional new data to become a smarter system.

4.4 Recommendations

Therefore, this research project had some limitations. For example, the survey responders only got 258 people from several locations. Perhaps in the next project, we will have more data and be able to analyze it and hopefully get better results. A minimum of 500–1000 respondents are involved in each project. Perhaps each project will have different sales strategies and get a better result.

Trying to use other algorithms either in classification and clustering modeling. According this research project, the next step in the development phase and the modeling will be used in the real business case as acting like a machine learning tool.

REFERENCES

[1] M. Galinium, "Integrating data mining technique and AHP in market analysis to propose new product development in real estate," in *IOP Conference Series: Materials Science and Engineering*, 2017, vol. 166, no. 1, p. 12030.

[2] P. Wazurkar, R. S. Bhadoria, and D. Bajpai, "Predictive analytics in data science for business intelligence solutions," in *2017 7th International Conference on Communication Systems and Network Technologies (CSNT)*, 2017, pp. 367–370.

[3] M. Thamarai and S. P. Malarvizhi, "House Price Prediction Modeling Using Machine Learning," *Int. J. Inf. Eng. Electron. Bus.*, vol. 12, no. 2, pp. 15–20, 2020, doi: 10.5815/ijieeb.2020.02.03.

[4] C. Pascal, S. Ozuomba, and C. kalu, "Application of K-Means Algorithm for Efficient Customer Segmentation: A Strategy for Targeted Customer Services," *Int. J. Adv. Res. Artif. Intell.*, vol. 4, no. 10, pp. 40–44, 2015, doi: 10.14569/ijarai.2015.041007.

[5] Y. Mulyano, R. A. Rahadi, and U. Amaliah, "Millennials Housing Preferences Model in Jakarta," *Eur. J. Bus. Manag. Res.*, vol. 5, no. 1, 2020.

[6] K. Y. Ngiam and W. Khor, "Big data and machine learning algorithms for healthcare delivery," *Lancet Oncol.*, vol. 20, no. 5, pp. e262–e273, 2019.

[7] D. Faggella, "What is Machine Learning?," *Emerj.*, 2020.

[8] Z. Sun, H. Zou, and K. Strang, "Big data analytics as a service for business intelligence," in *Conference on e-Business, e-Services and e-Society*, 2015, pp. 200–211.

[9] R. Y. K. Lau, S. S. Y. Liao, K.-F. Wong, and D. K. W. Chiu, "Web 2.0 environmental scanning and adaptive decision support for business mergers and acquisitions," *MIS Q.*, pp. 1239–1268, 2012.

[10] J. Lopes, T. Guimarães, and M. F. Santos, "Predictive and prescriptive analytics in healthcare: a survey," *Procedia Comput. Sci.*, vol. 170, pp. 1029–1034, 2020.

[11] N. W. Grady, J. A. Payne, and H. Parker, "Agile big data analytics: AnalyticsOps for data science," in *2017 IEEE international conference on big data (big data)*, 2017, pp. 2331–2339.

[12] J. Schleier-Smith, "An architecture for agile machine learning in real-time applications," *Proc. ACM SIGKDD Int. Conf. Knowl. Discov. Data Min.*, vol. 2015-Augus, pp. 2059–2068, 2015, doi: 10.1145/2783258.2788628.

[13] C. Kurniawan, L. C. Dewi, W. Maulatsih, and W. Gunadi, "Factors Influencing Housing Purchase Decisions of Millennial Generation in Indonesia," *Int. J. Manag.*, vol. 11, no. 4, 2020.

[14] T. Wambsganss, N. Molyndris, and M. Söllner, "Unlocking transfer learning in argumentation mining: A domain-independent modelling approach," *Proc. 15th Int. Conf. Bus. Inf. Syst. 2020 "Developments, Oppor. Challenges Digit. WIRTSCHAFTSINFORMATIK 2020*, no. February, 2020, doi: 10.30844/wi_2020_c9.

Color Palettes Overview After Thresholding Process with Default Methods of *ImageJ* or FIJI*

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ABSTRACT

Coloring techniques in life sciences continue to progress, which have now used deep learning in the staining stage to create virtual staining. Usually, manual staining produces an image with a more vigorous color intensity than virtual staining. This study aims to obtain an overview of the color palette (310 colors) after processing with the default threshold method in *ImageJ* v1.53s or FIJI (*ImageJ2*) version 2.3.0/1.53q with several variations of the color threshold and color space, which helps determine algorithms in image processing.

The variants of the color threshold were (red, white(W), black(B), and B+W). The color space variants were hue-saturation-brightness (HSB), red-green-blue (RGB), Lab, and YUV. The background variant used in the image processing in this study is dark. Later, after the image is binarized, the object in the image to be analyzed is colored black.

The separation results of 16 descriptions of threshold color and color space variants showed that the combination with HSB color space is the most sensitive to color differences, reducing red color the most. In contrast, the RGB color space is the least susceptible to color differences. Lab and YUV color spaces have almost the same segmentation effect. The results of this study not only can be applied in analyzing all types of manual or digital images in all branches of science and art.

CCS CONCEPTS

• **Image processing**; • **Imaging**; • **Medical Technologies**;

KEYWORDS

Thresholding, Binarization, Staining, Color

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1 INTRODUCTION

Before an image is analyzed, the image must go through image processing stages. The image processing stage aims that later what is analyzed digitally is the object of research. The image is first enriched, segmented at the processing stage, and then enters the binarization process (1).

We will obtain a clearer image at the enrichment end. Image segmentation is essential in several computer vision and image processing applications. In life sciences, segmentation is a crucial tool in detecting and describing particular objects in the image of cells, tissues, and organs of living things by separating the specific object from other parts and the image background.

Thresholding is one of the oldest and most existent image segmentation techniques (2) (3). Segmentation can use thresholding based on gray level, color, intensity, texture, depth, or movement. This study examines the setting of boundaries based on pixel intensity in natural images. In this paper, thresholding is carried out based on color values in natural images.

The threshold value of each image pixel will be binary so that the target object is separate from the non-target part, including the background. We select the more precise thresholding technique in the segmentation stage; after binarization, noise or artifacts in the image are reduced and even lost, and we can separate the target object from other parts of the image (4).

ImageJ is an open-source program which Java-based software that analyzes images. There are hundreds of plugins that operate under ImageJ. We can use these plugins to obtain quantitative data from research in various fields of science. The data are mainly related to two basic quantities: length and luminous intensity and their derivates. Currently, ImageJ has 17 threshold methods. One of them is the default. In *ImageJ*, the threshold process involves three things: the threshold method, threshold color, and color space. FIJI (*ImageJ2*) is *ImageJ* for Mac OS.

In the world of health, most of these images result from conventional or virtual staining (5) (6) (7). The staining involves one or more colorants or color indicators (for digitally generated and even virtual images) (8) (9). Digital pathology is an application of deep learning. Deep learning is part of machine learning. Digital pathology helps pathologists quickly extract the appearance of patterns from specific tissue preparations. The provisions that contain information about colors indicating target, non-target, and background will guide the observers of staining results (10).

Several research results have informed how to segment an image using several thresholding techniques and mathematical calculations (11)(12)(3)(13). Usually, these mathematical calculations are in the corridor of MATLAB applications. The overview of our results

Table 1: Combinations of threshold variants in the default threshold method of *ImageJ* or FIJI

No. of combination	Threshold color	Color space
1.	Red	HSB
2.	Red	RGB
3.	Red	Lab
4.	Red	YUV
5.	White	HSB
6.	White	RGB
7.	White	Lab
8.	White	YUV
9.	Black	HSB
10.	Black	RGB
11.	Black	Lab
12.	Black	YUV
13.	Black and White	HSB
14.	Black and White	RGB
15.	Black and White	Lab
16.	Black and White	YUV

informed about of the results from a binary image of 310 color palettes segmented using a variant of the IsoData thresholding method, namely the default of the thresholding method contained in *ImageJ* or FIJI, in all combinations of threshold color and color space included in the application.

This study aims to obtain an overview of the color palette after processing with the default threshold method in *ImageJ* or FIJI (*ImageJ2*) with several variations of the color threshold and color space. We can use this overview to determine the variance of the threshold color and color space in the thresholding process after obtaining information on the color provisions of the target object in the reading guidelines for each coloring technique (12). Since the overview was not the result of statistically calculating the grayscale value of the neighborhood pixel for each image pixel, if the type of segmentation is classical threshold image segmentation, we can use the summary (14) (15) (13).

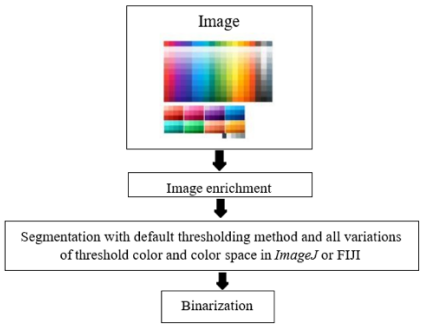


Figure 1: Flowchart of The Color Palettes Image Processing

2 MATERIAL AND METHODS

The color palettes were dummies of the color palettes in https://hexcolorspicker.com/tools/materialui/colors.html (209 colors) (16), and https://afrizatul.com/situs-flat-design/ (101 colors)(17). The shape of each palette is square (Fig. 1). Palettes selected from both sites are placed in a single-page word file converted to TIFF (Temporary Instruction File Format) format. The threshold method used is *ImageJ*'s default threshold method. All variants in the color threshold and color space in *ImageJ* v1.53s or FIJI (*ImageJ2*) version 2.3.0/1.53q are combined. Threshold color variants include red, white, black, and B+W (B&W). Color space variants include hue-saturation-brightness (HSB), red-green-blue (RGB) (11), Lab, and YUV. Sixteen combinations resulted from the threshold color and color space variants, each amounting to 4 (Table). The selected background was dark. According to the purpose of the study, image processing was not set or calibrated in length units.

Image>Adjust>Color Threshold (Fig. 2a.) is the order of the icons clicked before selecting the variant. After selecting the variant (Fig. 2b.), click 'Select' (Fig. 2c.).

After the thresholding process is completed (Fig. 2c.), proceed with binarization (Fig. 3). Binarization is started by clicking 'Process' on the toolbar. After 'Process' is activated, 'Binary,' then 'Make Binary' is clicked (Fig. 3). Figure 1 below shows the flow of all the image processing steps described previously. Calculating the reduced number of color palettes is calculated by summing the reduced number of color palettes contained in an extensive rectangular color palette consisting of 209 color palettes. Several smaller color palette groups below (including a rectangular group composed of 5 color palettes and eight rectangles comprised of 12 color palettes each) make it easier for us to identify the reduction that has occurred quickly. The first threshold combination (Table) process clarified below the thresholding and binarization processes. The whole process of thresholding and binarization used *ImageJ* and FIJI.

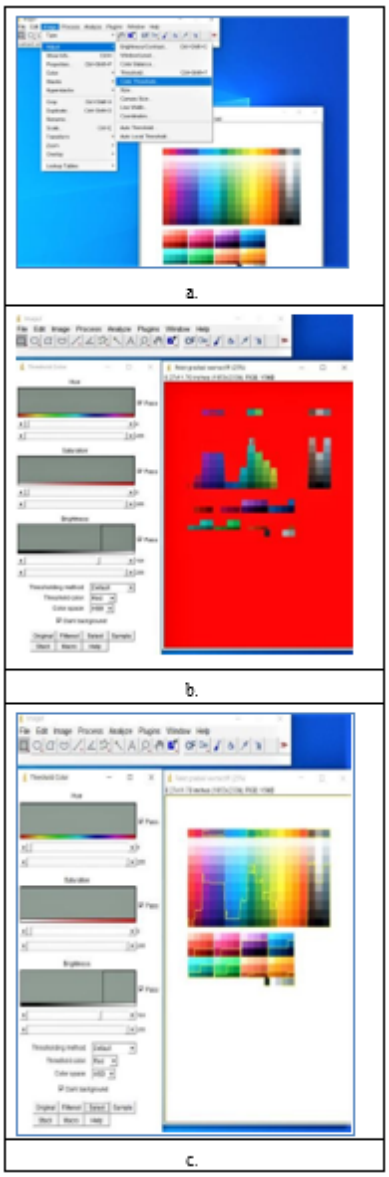


Figure 2: Thresholding Process of The First Threshold Combination

3 RESULTS AND DISCUSSION

The default threshold method of *ImageJ* is a variation of the IsoData algorithm. The IsoData threshold method divides the object and background based on the initial threshold value, then the average pixels at or below the threshold and the pixels above are calculated. The quotient of the sum of the average background pixel values and the average object values produced the threshold value. In the threshold process with the default threshold method of *ImageJ*, there are steps to return the same pixel value by activating the 'Ignore black' and 'Ignore white' functions (18). From all threshold

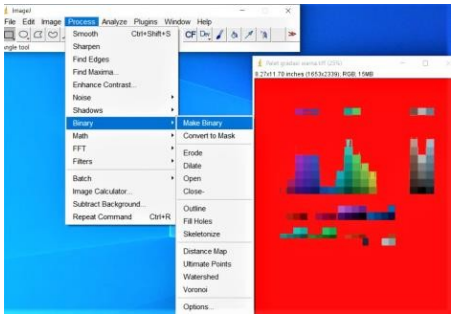


Figure 3: The Beginning of The Binarization Process of The First Threshold Combination

combinations, there were only four variations of results. The difference only occurs between different color spaces. Therefore, the results presented in this article are only four of the combinations with a white threshold.

The thresholding results from thresholding combinations with the color space of HSB (Fig. 4a.) and its binarization (Fig. 4b.) showed that the processes reduced the yellow and orange colors by 100%, so the yellow and orange objects will not be presented in the post-binarization process. Red, blue, purple, and brown decreased by 91% (20/22), 79% (26/33), 59% (13/22), and 27% (3/11). The combination group with the RGB color space variant showed the threshold result that reduced the blue color the least, only 27% (5/33) (Fig. 4c.). The groups reduced red, purple, green, yellow, orange, brown, and black colors by 23% (5/22), 23% (5/22), 36% (8/22), 27% (6/ 22), 36% (4/11) and 41% (9/22).

Figure 4.e. showed that the combination of the threshold with Lab color space reduced brown, red, green, purple, orange, and blue by 36% (4/11), 32% (7/22), 32% (7/22), 36% (16/44), and 48% (16/33). This combination group reduces the yellow color ultimately (100%). The reduced colors in combination with the *Lab* and YUV color space were not significantly different (Fig. 4e., and Fig. 4g.) because Lab and YUV color space are both converted from RGB color space. Lab color space consists of brightness (L), component *a* (green-red axis), and component *b* (blue-yellow axis). In the RGB to Lab conversion process, we must convert RGB colors to the XYZ color space with formula (19). There are publications of research results that inform the use of the Lab' color space in image processing of tissue preparations but do not use the default threshold method of *ImageJ* (20). The YUV color space consists of a luminance/brightness component (Y) and two color/chrominance components (chroma, U, and density, V).

The data provide information on the combination of the threshold with the HSB color space variant. We can choose the combination in the threshold process for objects that are colored or colored brown and purple. Still, both colors must not exist in the same image.

The overview of color palettes a, c, e, and g resulted from combining the threshold color white, color space HSB, RGB, Lab, and YUV before the 'Select' toolbar was clicked. Figure b, d, f, and h represent the binarization results of a, c, e, and g.

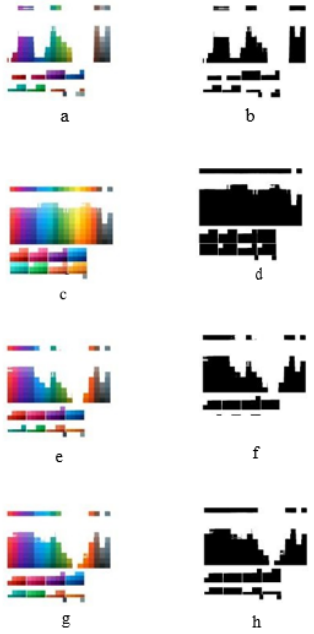


Figure 4: Overview of Color Palettes Before and After Binarization

The whole process of thresholding and binarization used *ImageJ* and FIJI. Figure 4.b., 4.d., 4.f., 4.g., and 5.b. were the example image processing results using FIJI. The results of thresholding with *ImageJ* were the same as the result of thresholding done with FIJI. However, the object color (black) in FIJI binarization results was the background color in the results with *ImageJ*.

We can also perform imaging analysis on various staining results in biomedical sciences, such as Hematoxylin-Eosin (HE), immunohistochemical and Gram stains. We usually stain cells or body tissues with HE and immunohistochemical stains and usually stain bacteria with Gram stain. We can digitally analyze the objects colored purple in the HE and Gram-stained images using the threshold combination groups with the color space of HSB. However, we can not analyze objects colored red in both stains' results by the thresholding combination because the thresholding significantly reduced all things colored red. This thresholding combination distinguishes objects stained with brown from things colored light blue the combinations because their binarization reduces all light blue colors. However, we can not use them to differentiate dark brown objects from dark blue ones.

All combinations can prove the existence of an object in the form of a yellow line between red, blue, green, brown, or black objects that are not after binarization. However, the results of the binarization of all segmentation of all combinations cannot distinguish between objects that are red, purple, blue, green, brown, or black. It caused all threshold combinations not to reduce these colors 100%.

The acquisition of quantitative data regarding collocation will be helpful for the process of analyzing the observed image using a microscope other than a fluorescence or confocal microscope along with the microscope's built-in software. Users of both microscopes can obtain quantitative collocation data by deactivating the fluorescent light channel feature and leaving the other fluorescent light channel feature active and vice versa (21). This research proved that the default threshold method of *ImageJ* is only susceptible to yellow and white colors. To distinguish dark red, purple, dark blue, brown, and black objects, one must use a threshold method that is more sensitive to these colors. HSB is the most sensitive to color intensity among the four color spaces.

After the image is binarized, it can only be analyzed with one of *ImageJ*'s main features, such as 'Analyze,' or can be continued with the appropriate plugin (18). A plugin is a computer program that adds to the functionality of the main program. *ImageJ* has hundreds of plugins. Sometimes in an image processing algorithm, there is more than one binarization step. The next binarization begins with segmentation using a threshold based on things different from the previous threshold, which is more specific according to image processing and analysis.

ImageJ currently has 17 thresholding methods, four threshold colors, and four color spaces, so there are 272 threshold combinations available in ImageJ. This study only studied 5.8% (16/272) of the existing threshold combinations in *ImageJ* or Fiji today. Several research results have informed the use of 16 of the 17 threshold methods available in *ImageJ* (one threshold method, IJ_IsoData, was not examined in these studies). These studies did not try all the available threshold colors and color space variants (4 variants each) (13)(22). In addition, the colors involved in the shade of objects in the two studies did not vary much, only the color of the documented cells. However, the studies showed the sensitivity of each threshold method to the intensity of a specific color and the regularity or irregularity of the object's shape (s).

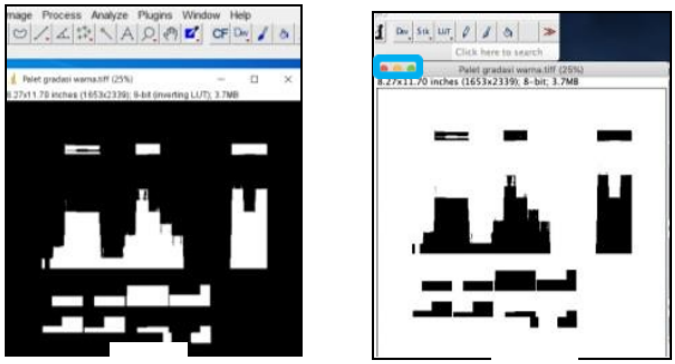
We can use these research results to analyze all digitally generated images in general or in deep learning processes. Although the sensitivity of the threshold method is not as sensitive (to the object's shape), the threshold method is non-default.

Sixteen other thresholding methods (besides the default) have specific mathematical properties and are more detailed than the default. We can use the data of combination information for image processing with a short algorithm or segmentation stages before the first binarization on image launch with relatively long algorithms. We can implement these research results in analyzing all types of all digitally generated images in general or in deep learning processes in all branches of science and art.

4 CONCLUSION

Of the 16 combinations studied, the combination of thresholding with the HSB color space is a threshold that can ideally reduce orange and yellow colors, reducing red color the most. Apart from the various specific purposes of immunohistochemical staining, this combination is quite suitable for observing brown target objects, for example, immunohistochemical staining results. The combination with the RGB color space can reduce the minor colors. The combination of thresholding with *Lab* and YUV color spaces has almost the same segmentation effect.

We need to continue this research to determine the effect of threshold combinations on various colors, essentially represented by pixel intensity.



a. b.

Figure 5: Binarization Results Display. The results of the first combination binarization are in *ImageJ* (a) and FIJI (b).

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REFERENCES

[1] Khan A, Garner R, Rocca M La, Salehi S, Duncan D. A Novel Threshold- Based Segmentation Method for Quantification of COVID-19 Lung Abnormalities. Signal, Image Video Process [Internet]. 2022; Available from: https://doi.org/10.1007/s11760-022-02183-6

[2] Kulkarni N. Color Thresholding Method for Image Segmentation of Natural Images. Int J Image, Graph Signal Process. 2012;4(1):28–34.

[3] Guruprasad P. Overview Of Different Thresholding Methods In Image Processing. TEQIP Spons 3rd Natl Conf ETACC. 2020;(June).

[4] Ramírez-Ortegón MA, Märgner V, Cuevas E, Rojas R. An optimization for binarization methods by removing binary artifacts. Pattern Recognit Lett. 2013;34(11):1299–306.

[5] Chatrian A, Colling RT, Browning L, Alham NK, Sirinukunwattana K, Malacrino S, *et al.* Artificial intelligence for advance requesting of immunohistochemistry in diagnostically uncertain prostate biopsies. Mod Pathol [Internet]. 2021;34(9):1780–94. Available from: http://dx.doi.org/10.1038/s41379-021-00826-6

[6] Alturkistani HA, Tashkandi FM, Mohammedsaleh ZM. Histological Stains: A Literature Review and Case Study. Glob J Health Sci. 2015;8(3):72–9.

[7] Rivenson Y, Wang H, Wei Z, de Haan K, Zhang Y, Wu Y, *et al.* Virtual histological staining of unlabelled tissue-autofluorescence images via deep learning. Nat Biomed Eng. 2019;3(6):466–77.

[8] Kayser K, Görtler J, Bogovac M, Bogovac A, Goldmann T, Vollmer E, *et al.* AI (artificial intelligence) in histopathology - From image analysis to automated diagnosis. Folia Histochem Cytobiol. 2009;47(3):355–61.

[9] Linden MA, Sedgewick GJ, Ericson M. An Innovative Method for Obtaining Consistent Images and Quantification of Histochemically Stained Specimens. J Histochem Cytochem. 2015;63(4):233–43.

[10] Adler J, Parmryd I. Quantifying colocalization: Thresholding, void voxels, and the Hcoef. PLoS One. 2014;9(11).

[11] Journal SI, Science C. A Thresholding Method for Color Image Binarization Kalavathi P Department of Computer Science and Applications Gandhigram Rural Institute – Deemed University, Gandhigram, Tamil Nadu, India. 2014;1(September):31–40.

[12] N S, S V. Image Segmentation By Using Thresholding Techniques For Medical Images. Comput Sci Eng An Int J. 2016;6(1):1–13.

[13] Nichele L, Persichetti V, Lucidi M, Cincotti G. Quantitative evaluation of ImageJ thresholding algorithms for microbial cell counting. OSA Contin. 2020;3(6):1417.

[14] Wang D, Shi L, Wang YXJ, Man GCW, Heng PA, Griffith JF, *et al.* Color quantification for evaluation of stained tissues. Cytom Part A. 2011;79 A(4):311–6.

[15] Ekhande PN, Rumane SA, Ahire MA. Document Image Binarization Using Image Segmentation Algorithm in Parallel Environment. 2015;4(1):360–6.

[16] Material Design Colors [Internet]. [cited 2022 Jul 10]. Available from: https://hexcolorspicker.com/tools/materialui/colors.html

[17] Rizki BA. Situs Flat Design Terbaik Untuk Editing dan Pewarnaan [Internet]. [cited 2022 Jul 10]. Available from: https://afrizatul.com/situs- flat-design/

[18] Ferreira T, Rasband W. ImageJ User Guide. Vol. 1.46r, Image J user Guide. 2012.

[19] Ibraheem N a, Hasan MM, Khan RZ, Mishra PK. Understanding Color Models: A Review. ARPN J Sci Technol. 2012;2(3):265–75.

[20] Piórkowski A, Gertych A. Color normalization approach to adjust nuclei segmentation in images of hematoxylin and eosin stained tissue. Adv Intell Syst Comput. 2019;762:393–406.

[21] Lee W, Kim H, Bae PK, Lee S, Yang S, Kim J. A single snapshot multiplex immunoassay platform utilizing dense test lines based on engineered beads. Biosens Bioelectron. 2021;190(May).

[22] Brocher J. Qualitative and quantitative evaluation of two new histogram limiting binarization algorithms. Jan Brocher Int J Image Process. 2014;(8):30.

Performance Evaluation of Systematic Option Trading Strategies Using Entry and Exit Points Predicted by Machine Learning

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ABSTRACT

In option trading, there are various technical indicators that can be used to determine entry signals. There are also various setups for systematic option trading strategies. The objective of this research is to evaluate the performance of systematic option trading strategies using entry signals generated by machine learning with technical indicators as predictors. To achieve this objective, a two-phase study is conducted. During Phase 1, machine learning algorithm is utilized to generate entry signals based on support and resistance prediction. Based on these signals, various option trading setups are evaluated in the Phase 2 to find an optimal setup that yield the highest ROC.

Neural network algorithm with 5 hidden layers and 100 neurons in each layer is found to be the best algorithm to predict support and resistance to be used as signals. The back-testing results show that option trading strategy that yield the highest ROC is debit spread strategy with delta 0.15 setup and DTE 30 setup, which results in 399% annual ROC. The benchmark test results show that the performance of option trading using machine learning entry signals prediction outperforms option trading with single technical indicator entry signals, and that option trading outperforms the regular stock trading.

CCS CONCEPTS

• **Computing methodologies** → Machine learning; Machine learning approaches; Neural networks.

KEYWORDS

Machine learning, Option trading strategy evaluation, Support-resistance prediction, Systematic option trading, Trade expectancy

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1 INTRODUCTION

In general, stock price is always fluctuating. Some people believe that good news will drive a stock price up and bad news will drive it down. However, this assumption does not work in every case. Therefore, it's very challenging to predict the price movement in the stock market. The problem is that in order to make profit in stock trading, a trader must buy a stock and sell it at a higher price and it requires high accuracy in predicting stock price movement, which is very challenging.

Beside stock, there's another product that is traded in the stock market called option. Option price, also known as premium, is complex in its calculation because it is derived from various factors, such as underlying stock price, time value, and volatility. This complexity benefits option traders as it allows traders to utilize other factors than a stock price in generating profit. Therefore, in option trading, a trader doesn't have to be very accurate in predicting the stock price movement. There are various trading strategies and pre-determined trading rules that can be used in option trading. Advanced trading strategies combine two or more option type, strike price, and/or expiration. Some examples of strategies that combine two option strike prices are bull call spread strategy, bull put spread strategy, bear call spread strategy, and bear put spread strategy. Bull call spread is an option trading strategy for a bullish market using a pair of call options that is constructed by buying a call option with a particular strike price and expiration date, and then selling another call option with a higher strike price but same expiration date. This strategy is a debit strategy which means a bull call spread buyer will have to pay a certain amount of cash when entering the trade. Bull put spread is an option trading strategy for a bullish market using a pair of put options that is constructed by selling a put option with a particular strike price and expiration date, and then buying another put option with a lower strike price but same expiration date. This strategy is a credit strategy which means a bull put spread seller will receive a certain amount of cash when entering the trade. Bear call spread is an option trading strategy for a bearish market using a pair of call options that is constructed by selling a call option with a particular strike price and expiration date, and then buying another call option with a higher strike price but same expiration date. This strategy is a credit strategy which means a bear call spread seller will receive a certain amount of cash when entering the trade. Bear put spread is an option trading strategy for a bearish market using a pair of put options that is constructed by buying a put option with a particular strike price and expiration date, and then selling another put option with a lower strike price but same expiration date. This strategy is a debit strategy which means a bear put spread buyer will have to pay a certain amount of cash when entering the trade.

Option trading strategy with pre-determined rules or criteria for entering and exiting trade is also known as systematic option trading strategy. [1] Entry criteria can be some entry signals and exit criteria can be some exit signals. Entry and exit signals are the points where a trader is suggested to enter or exit a trade. Oftentimes, these points are also identified as support and resistance points which is defined as the two price points where a stock price is assumed to fluctuate in between. [2] Support point is a point where a stock price is assumed to reverse from going down to going up. Resistance point is a point where a stock price is assumed to reverse from going up to doing down. In an uptrend (bullish) market, when the overall stock market moves upward, moving average line often acts as support line where support points lie. In a downtrend (bearish) market, when the overall stock market moves downward, moving average line often acts as resistance line where resistance points lie. In a neutral market, when the stock market moves sideways, moving average cannot be used to determine support and resistance. Hence, traders will use horizontal support and resistance line instead to determine support and resistance points. [3] Support and resistance points can be obtained both from various technical indicators that are available in trading platforms and from the market analysts on the Internet [2], or though machine learning prediction.

To utilize machine learning for support and resistance points prediction, training data of the true support and resistance points are needed. These points can be calculated using numerical differentiation method, a method that uses the numerical derivative of the historical closing price. Various algorithms can be implemented for machine learning such as random forest, support vector machine, naïve bayes, and neural network. [4] The best machine learning algorithm can be chosen by evaluating the testing scores: Accuracy, Recall, Precision, F1 score, and AUC score measurement. [5]

Different systematic option trading strategies allow for different combination of probability of winning or losing and risk-reward ratio, therefore result in different trading profit or return. In general, option trading strategy with the highest expected return is desirable. Unfortunately, there's a trade-off where a high return strategy usually comes with a high risk-reward ratio and low probability of winning. One of the metrics to evaluate a trading strategy's performance is expectancy value. Expectancy value is a value that an investment will gain in the future. [6] Based on Van K Tharp expectancy theory, expectancy value is the average profit or loss a trader can expect to make per dollar risked over a large number of trades. Expectancy value is calculated by multiplying each of the possible outcomes by the probability each outcome will occur and then summing all of those values. [7] The other metric is return on capital (ROC) which measures the efficiency of capital usage to generate profit. ROC is calculated by dividing trading profit with the total amount of capital employed or used. [8] There are four ways to use option: for income, insurance, hedging, or speculation. In one extreme conservative side, option is a powerful tool for generating income through collecting premiums. [9] The other extreme way to use option is for speculation or leverage. Option as leverage tool allows people to maintain high efficiency in capital usage because it requires a small amount of capital to generate a high return, which results in high return on capital (ROC), but with a lower probability of winning. This study aims to evaluate the performance of various systematic option trading strategies using entry signals generated by machine learning algorithm with technical indicators as predictors.

2 LITERATURE REVIEW

Option is a derivative security of another security such as stock. It is a contract between its buyer and seller to trade a certain underlying stock within a specific range of time at an agreed-upon stock price. There are two types of option, call option and put option. Put option is a contract that gives its buyer a right to sell an underlying stock at a specific price (also known as strike price) before or at a specific date (also known as expiration date). Upon buying a put option, the buyer expects the underlying stock price to go down. Call option gives its buyer a right to sell an underlying stock at a specific strike price before or at the expiration date. Upon buying a call option, the buyer expects the underlying stock price to go up. [10]

In recent years, more researchers did scientific studies on quantitative trading strategies optimization, especially with the advancement of data analytics and machine learning. The result of these studies is significant in minimizing subjective judgment of individuals in the market by breaking through human's limit in time and space and controlling the risk accurately and effectively. [5] Vanstone and Finnie (2009) conducted a study to present a methodology for designing robust mechanical trading systems using artificial neural network. [11] Persio and Honchar (2016) conducted a study to exploit different neural networks architectures to predict stock market indices trend movements. [12] Zi et al. (2017) conducted a study to build a quantitative trading strategy through neural network algorithm and the fisher linear discriminant. [5] Enke and Amornwattana (2008) conducted a study to develop a hybrid option trading system that incorporates both volatility and return forecasting using neural network. [13] Ucar et al. (2013) conducted a study to propose a trading model with two-level optimization using the value of RSI technical indicator at the first level, and then to the strike price and days to expiration of covered call strategy at the second level. [14] Pakhrudin et al. (2020) conducted a study to develop a system to evaluate trading system performance with Van K Tharp expectancy theory. [6] Ramasamy and Prabakaran (2018) conducted a study to investigate the optimal strategies and performance of option trading by calculating the cumulative positive return. [15]

3 METHODOLOGY

To achieve the objective of this study, a two-phase study is conducted. There are two version of dataset for Phase 1. First version dataset utilizes historical data of technical indicators and SPY during 2002-2009 as training dataset and historical data of technical indicators and SPY during 2010-2016 as testing dataset. Second version dataset utilizes historical data of technical indicators and SPY during 2002-2013 as training dataset and historical data of technical indicators and SPY during 2014-2016 as testing dataset. Phase 1 and Phase 2 of this study uses historical option data of SPY during 2017-2019.

Before entering Phase 1, price trend is determined. Moving average lines are used as a parameter for determining price trend. [16] If the 50-days simple moving average line (50SMA) is above the 150-days simple moving average line (150SMA), price is considered

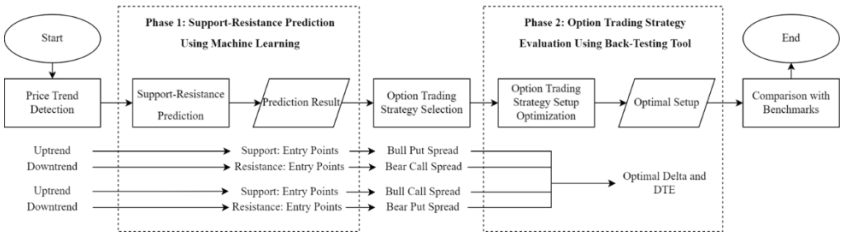

Figure 1: Two-Phases Study Framework

as moving in an uptrend. If the 50SMA is below the 150SMA, price is considered as moving in a downtrend. During Phase 1, machine learning algorithm is utilized to generate entry signals based on support and resistance prediction. Technical indicators are used as features in the machine learning prediction. Technical analysis is an analysis of a stock based on statistical analysis on market data, such as stock price and volume. Technical analysis is purely based on stock chart to extract trading signal. [17] In technical analysis, traders observe the movement and behaviour of technical indicators graph. However, historical data of technical indicators that is collected contain only absolute values. Therefore, historical data needs to be pre-processed before being used as features in machine learning by calculating the slopes of technical indicators values. For example, Stochastic technical indicator is used by observing the slope of %K line and %D line. Data pre-processing includes calculating the Slope of %K line by subtracting today's %K value with the previous day's value and dividing the result by number of days.

After data pre-processing is done, feature selection is performed using "Rank" feature in Orange software. There are seven different combination of features that are tested. The best machine learning algorithm is chosen based on Accuracy, Recall, Precision, F1 score, and AUC score measurement and is used to predict the support and resistance points that are used as entry signals for Phase 2.

Using the entry signals generated in Phase 1, various option trading setups are evaluated in the Phase 2 using back-testing tool to find an optimal setup that yield the highest ROC. Back-testing method is doing simulation of the systematic trading strategy using historical market data. [18] Two options trading strategies that are selected to be evaluated are credit spread strategy and debit spread strategy. Credit spread strategy consists of bull put spread and bear call spread. Debit spread strategy consists of bull call spread and bear put spread.

Finally, the trading result from Phase 2 is compared with two benchmarks. The first benchmark is entry signal benchmark, which is the result of option trading using single technical indicator's entry points without machine learning. The second benchmark is trading strategy benchmark, which is the result of stock trading without option using the same entry and exit points predicted by machine learning in Phase 1. The overview of Two-phases study framework is represented in Figure 1.

3.1 Machine Learning Parameter Setups

There are four machine learning algorithms are tested using Orange software: Support Vector Machine (SVM), Random Forest (RF), Neural Network (NN), Naïve Bayes. Various parameter setups are tested for SVM, RF, and NN.

3.2 Back-testing Setups

There are two options trading strategies that are tested in this research: credit spread and debit spread. Credit spread consists of bull put spread that is entered when the machine learning prediction result is minima during an uptrend, and bear call spread that is entered when the machine learning prediction is maxima during a downtrend. For each options trading strategy, there are 12 setups that are back-tested. These 12 setups are developed from combination of 3 different days to expiration (DTE) setups and 4 different delta setups. The most commonly used DTE setup for credit spread strategy is 30 days where the theta decay accelerates, but in this research, 3 different DTE setups are back-tested: 15 DTE, 30 DTE, and 45 DTE to compare the effect of using shorter and longer DTE. The delta setups that are back-tested are: delta 0.45, delta 0.35, delta 0.25, and delta 0.15.

4 EXPERIMENTAL RESULTS

4.1 Machine Learning Testing Results

4.1.1 Machine Learning Algorithm Comparison. To determine the best machine learning algorithm, some testing is conducted using Orange. The first test uses training and testing dataset version 1 with various features combination. The result shows that Naïve Bayes has the highest average AUC of 0.721848962, SVM A has the highest average accuracy of 0.662101937, and RF C has the highest average F1 score of 0.580595899. The second test uses training and testing dataset version 2 with various features combination. The result shows that NN B has the highest average AUC of 0.729949194, SVM A and SVM B has the highest average accuracy of 0.665219853, and NN C has the highest average F1 score of 0.58273537.

In general, increasing the number of neurons and hidden layers reduces the testing score of NN algorithm. However, increasing the number of trees increases the testing score of RF algorithm in general. Training and testing dataset version 2 has better average AUC, accuracy, and F1 score than dataset version 1.

4.1.2 Features Combination Comparison. After conducting testing using training and testing dataset version 1 with various machine learning algorithms, the result shows that features combination "Rank 7 Features" has the highest average AUC of 0.711061093 and also the highest F1 score of 0.566789887. Features combination "Rank 4 Features" has the highest average accuracy of 0.634826999. After conducting testing using training and testing dataset version

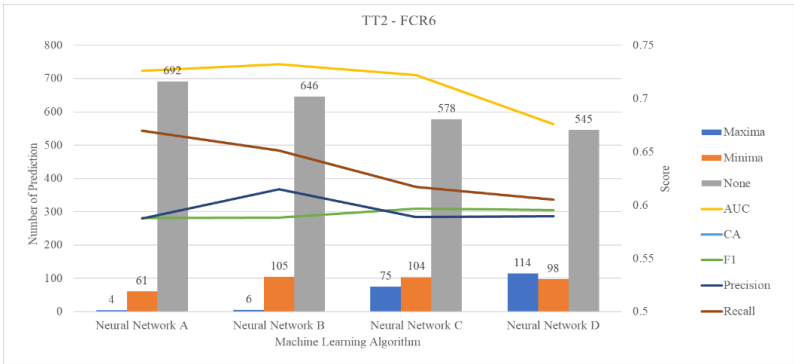

Figure 2: NN Algorithm Prediction Result Comparison

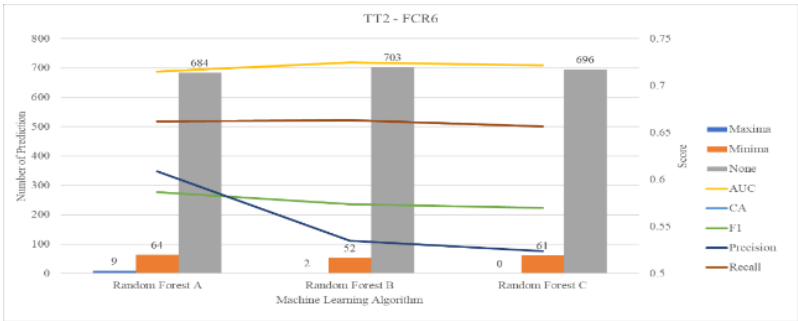

Figure 3: RF Algorithm Prediction Result Comparison

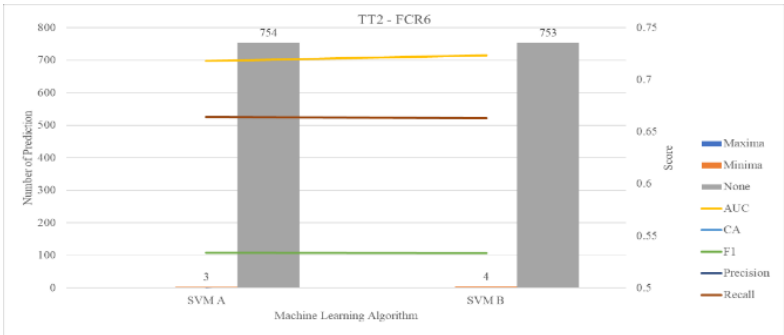

Figure 4: SVM Algorithm Prediction Result Comparison

2 with various machine learning algorithms, the result shows that features combination "Rank 8 Features A" has the highest average AUC of 0.634826999 and also the highest F1 score of 0.569416729. Features combination "Rank 3 Features" has the highest average accuracy of 0.643989432.

In general, increasing the number of features does not increase the testing score of machine learning. Training and testing dataset version 2 has better average AUC, accuracy, and F1 score than dataset version 1. In general, testing score of various machine learning algorithms are similar. However, it can be observed that similar AUC, CA, and F1 scores does not necessarily mean that the prediction results from the machine learning algorithms are also similar.

Figure 2, Figure 3, and Figure 4 represent the number of predictions made by various NN algorithm setup, various RF algorithm setup, and various SVM algorithm setup respectively. From these figures, it can be observed that the machine learning algorithm predicts imbalanced number of minima compared with the number of maxima prediction, except for NN C and NN D.

Increasing the number of neurons and hidden layers reduces the score of NN algorithm in general. However, algorithm with less neurons and hidden layers, in this case NN A, predicts less balanced number of minima compared with the number of maxima prediction. As the number of neurons and hidden layers are increased, the number of minima and maxima prediction is becoming

more balanced and more representing for the testing dataset. For example, the prediction result from NN A consists of 61 minima and 4 maxima, while the prediction result from NN D consists of 98 minima and 114 maxima. The testing dataset itself consists of 126 minima and 127 maxima. Therefore, a better testing score does not necessarily represent a better prediction result, and vice versa.

Despite the low testing score, when visualizing the prediction result of machine learning algorithms, it can be observed that the minima and maxima prediction might not be very accurate, but it is not totally missed. There are cases where the algorithms predict minima and maxima on the previous day of the actual minima and maxima, which is also acceptable.

4.2 Back-testing Results

4.2.1 Credit Spread Strategy.

Bull Put Spread Strategy. Theoretically, bull put spread strategy has a higher win rate and a lower loss rate as the delta gets lower. The back-testing result for various delta setup confirms this theoretical hypothesis.

Delta theoretically represents the probability of an option strike price to get hit at expiration date. Therefore, it represents an expected loss rate of a bull put spread strategy. For example, delta 0.45 represents 55% expected win rate and 45% expected loss rate of bull put spread strategy with delta 0.45 setup. However, based on the back-testing result, bull put spread with delta 0.45 setup has a win rate of 76.58% which is higher than the pre-assumed win rate of 55%. This finding indicates a strong bullish trend during the tested period which increases the win rate of the bull put spread strategy.

Despite the lowest win rate of 76.58%, the back-testing result shows that the ROC of bull put spread strategy is the highest at delta 0.45 setup (33.33%) compared with other delta setups. This finding indicates that during a strong bullish trend, delta 0.45 setup has the best yield for bull put spread strategy. On average, DTE 15 setup yields the best ROC (22.51%), followed by DTE 30 setup (22.78%) and DTE 45 setup (17.4%). However, DTE 45 setup has the highest win rate of 85.1% compared with the other setups. When looking into the individual setup, the back-testing result shows that delta 0.45 setup combined with DTE 30 setup has the best yield of 45% for bull put spread strategy during the tested period.

Bear Call Spread Strategy . Theoretically, bear call spread strategy has a higher win rate and a lower loss rate as the delta gets lower. The back-testing result for various delta setup confirms this theoretical hypothesis.

Delta theoretically represents an expected loss rate of a bear call spread strategy. For example, delta 0.45 represents 55% expected win rate and 45% expected loss rate of bear call spread strategy with delta 0.45 setup. However, based on the back-testing result, bear call spread with delta 0.45 setup has a win rate of 35.97% which is lower than the pre-assumed win rate of 55%. This finding indicates an unclear bearish trend during the tested period which decreases the win rate of the bear call spread strategy.

The back-testing result shows that the ROC of bear call spread strategy is the highest at delta 0.15 setup (-12.43%) compared with other delta setups. This finding indicates that during a bearish trend, delta 0.15 setup has the best yield for bear call spread strategy. On average, DTE 15 setup yields the best ROC (-8.16%), followed by DTE 45 setup (-23.08%) and DTE 30 setup (-26.4%). However, DTE 15 setup has the highest win rate of 67.19% compared with the other setups. When looking into the individual setup, the back-testing result shows that delta 0.15 setup combined with DTE 15 setup has the best yield of 6.25% for bear call spread strategy during the tested period. This setup also has the highest win rate of 93.75%.

4.2.2 Debit Spread Strategy.

Bull Call Spread Strategy. Theoretically, bull call spread strategy has a higher win rate and a lower loss rate as the delta gets higher. The back-testing result for various delta setup confirms this theoretical hypothesis.

Delta theoretically represents an expected win rate of a bull call spread strategy. For example, delta 0.45 represents 45% expected win rate and 55% expected loss rate of bull call spread strategy with delta 0.45 setup. However, based on the back-testing result, bull call spread with delta 0.45 setup has a win rate of 56.89% which is higher than the pre-assumed win rate of 45%. This finding indicates a strong bullish trend during the tested period which increases the win rate of the bull call spread strategy.

Despite the lowest win rate of 27.41%, the back-testing result shows that the ROC of bull call spread strategy is the highest at delta 0.15 setup (280.98%) compared with other delta setups. This finding indicates that during a strong bullish trend, delta 0.15 setup has the best yield for bull call spread strategy. On average, DTE 30 setup yields the best ROC (222.92%), followed by DTE 15 setup (164.27%) and DTE 45 setup (149.92%). DTE 30 setup also has the highest win rate of 51.05% compared with the other setups. When looking into the individual setup, the back-testing result shows that delta 0.15 setup combined with DTE 30 setup has the best yield of 345% for bull call spread strategy during the tested period.

Bear Put Spread Strategy. Theoretically, bear put spread strategy has a higher win rate and a lower loss rate as the delta gets higher. The back-testing result for various delta setup confirms this theoretical hypothesis.

Delta theoretically represents an expected win rate of a bear put spread strategy. For example, delta 0.45 represents 45% expected win rate and 55% expected loss rate of bear put spread strategy with delta 0.45 setup. However, based on the back-testing result, bear put spread with delta 0.45 setup has a win rate of 21.25% which is higher than the pre-assumed win rate of 45%. This finding indicates an unclear bearish trend during the tested period which decreases the win rate of the bear put spread strategy.

Despite the lowest win rate of 10.42%, the back-testing result shows that the ROC of bear put spread strategy is the highest at delta 0.15 setup (22.51%) compared with other delta setups. This finding indicates that during a bearish trend, delta 0.15 setup has the best yield for bear put spread strategy. On average, DTE 30 setup yields the best ROC (17.12%), followed by DTE 15 setup (-3.86%) and DTE 45 setup (-20.59%). DTE 30 setup also has the highest win rate of 21.88% compared with the other setups. When looking into the individual setup, the back-testing result shows that delta 0.15 setup combined with DTE 30 setup has the best yield of 90% for bear put spread strategy during the tested period.

Table 1: Comparison Between Machine Learning and Single Technical Indicator's Signals Performance

	Annual ROC	Max Capital Used (USD)	Win %	Loss %	Profit (USD)	Loss (USD)	Total Profit (Loss) (USD)
Credit Spread – ML Entry Signal	48%	2,735.70	80.18%	19.82%	10,143.50	6,205.90	3,937.60
Credit Spread – MACD Entry Signal	-12%	2,040.10	69.84%	30.16%	3,809.10	4,542.40	(733.30)
Debit Spread – ML Entry Signal	399%	497.40	28.18%	71.82%	9,758.20	3,805.50	5,952.70
Debit Spread – MACD Entry Signal	193%	246.40	23.44%	76.56%	3,496.20	2,070.60	1,425.60

Table 2: Comparison Between Option Trading and Regular Stock Trading Performance

	Annual ROC	Max Capital Used	Win %	Loss %	Profit	Loss	Total Profit (Loss)
Credit Spread – ML Entry Signal	48%	2,735.70	80.18%	19.82%	10,143.50	6,205.90	3,937.60
Debit Spread – ML Entry Signal	399%	497.40	28.18%	71.82%	9,758.20	3,805.50	5,952.70
Stock Trading – ML Entry Signal	2%	312,076.00	76.29%	23.71%	34,528.28	12,128.07	22,400.21

4.3 Benchmarking

4.3.1 Entry Signal Benchmark. Option credit spread strategy with machine learning entry signal results in a higher win rate compared with option credit spread strategy with MACD entry signal. The ROC from trading using machine learning entry signal is also higher than trading using MACD entry signal, as represented in Table 1. In summary, for credit spread strategy, machine learning signal outperform the single technical indicator signal.

Option debit spread strategy with machine learning entry signal results in a higher win rate and ROC compared with option debit spread strategy with MACD entry signal. Therefore, for debit spread strategy, machine learning signal also outperform the single technical indicator signal.

4.3.2 Trading Strategy Benchmark. Option trading strategy with machine learning entry signals results in a higher win rate compared with stock trading with same entry signals. Table 2 shows that option debit spread strategy yield the highest ROC, followed by option credit spread strategy and stock trading. In summary, option trading outperforms stock trading.

4.4 Return on Capital (ROC) Optimization

ROC is calculated by dividing the annual profit with the required capital. The process of determining the required capital begins by counting the number of open trade positions for each day of the testing period. The day that has the greatest number of open positions is the day when maximum amount of capital is required. This amount then is the required capital.

However, because the number of open positions fluctuate during the test period, the capital used also varies. There are only a few days where the maximum capital of USD 2,500 is required. Therefore, a capital of USD 2,000 already covers most of the trading days (92%). By limiting the maximum capital used to USD 2,000, the ROC increases from 48% to 57%. This example demonstrates that by limiting the maximum capital used to cover most of the trading days, the ROC for a specific trading strategy can be improved further. This process is done for the remainder of the tested strategies and the result is shown in Table 3.

Table 3: Comparison Between ROC of Non-Optimized and Optimized Capital Usage

	Annual ROC		Maximum Capital Used		Number of Days Covered
	Non-Optimized	Optimized	Non-Optimized	Optimized	
Credit Spread – ML Entry Signal	48%	57%	2,735.70	1,921.20	92%
Credit Spread – MACD Entry Signal	-12%	-23%	2,040.10	1,326.40	97%
Debit Spread – ML Entry Signal	399%	399%	497.40	497.40	100%
Debit Spread – MACD Entry Signal	193%	193%	246.40	246.40	100%
Stock Trading – ML Entry Signal	2%	3%	312,076.00	199,821.00	96%

5 CONCLUSION

This study has explored the usage of machine learning to predict entry signals for option trading and evaluated the optimal setup to yield the best ROC. NN C algorithm, an algorithm with 5 hidden layers and 100 neurons in each layer, is found to be the best algorithm to predict support and resistance to be used as trading signals. The ROC can be further improved by limiting the capital used to cover most (greater than 90%) of the trading days. The optimal setup of option trading strategy that yield the best ROC is debit spread strategy, which is a combination of bull call spread and bear put spread with delta 0.15 setup and DTE 30 setup. In observing the performance across different expiration date (DTE), there's no clear pattern that a particular DTE setup is universally optimal. The occurrence timing of support and resistance significantly affects the win rate of each DTE setup. Because such timing or cycle is random by nature, it is almost impossible to predict when the underlying price will expire within the profit zone. In comparison, delta setup shows a clearer correlation to the win rate and ROC.

The results of the benchmark tests show that the performance (ROC) of option trading using machine learning entry signals prediction outperforms option trading using single technical indicator entry signals. Furthermore, option trading ROC outperforms regular stock trading under the same entry signals predicted by machine learning. One of the advantages of option trading compared with regular stock trading is the ability to generate profits as long as the underlying stock remain within the profit zone. This research has shown that the robust nature of option trading makes it most suitable to be used with machine learning entry signals prediction because it can still perform well under certain level of prediction inaccuracies.

REFERENCES

[1] K. Perumal and E. Flint, "Systematic Testing of Systematic Trading Strategies," SSRN Electronic Journal, 2018.
[2] E. O. Yıldırım, M. Uçar and A. M. Özbayoğlu, "Evolutionary Optimized Stock Support-Resistance Line Detection for Algorithmic Trading Systems," 2019 1st International Informatics and Software Engineering Conference (UBMYK), pp. 1-6, 2019.
[3] C. D. Kirkpatrick II and J. Dahlquist, Technical Analysis: The Complete Resource for Financial Market Technicians Second Edition, New Jersey: FT Press, 2011.

[4] S. Ray, "A Quick Review of Machine Learning Algorithms," in International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMIT-Con), India, 2019.

[5] Y. L. Zi, B. Z. Yuan, Y. Z. Jia, X. Y. Xiao and G. L. Xin, "Research on Quantitative Trading Strategy Based on Neural Network Algorithm and Fisher Linear Discriminant," International Journal of Economics and Finance; Vol. 9, No. 2, pp. 133-141, 2017.

[6] K. Pakhrudin, K. A. Kamaruddin and F. Ahmad, "Trader Hub System Development Using Van K Tharp Expectancy Theory to Analyse Retail Forex Trading System Performance," Malaysian Journal of Computing, 5 (2), pp. 523-536, 2020.

[7] V. K. Tharp, Trade Your Way to Financial Freedom Second Edition, New York: McGraw-Hill, 2007.

[8] Tastyworks, Inc., "Return on Capital," [Online]. Available: https://www.tastytrade.com/definitions/return-on-capital#:~:text=Return%20on%20Capital%2C%20also%20known,total%20amount%20of%20capital%20used.&text=When%20we're%20trading%2C%20our,capital%20as%20efficiently%20as%20possible.. [Accessed 7 1 2022].

[9] M. Sincere, Understanding Options 2E, United States: McGraw-Hill, 2014.

[10] I. Ucar, A. M. Ozbayoglu and M. Ucar, "Developing a Two Level Options Trading Strategy Based on Option Pair Optimization of Spread Strategies with Evolutionary Algorithms," 2015 IEEE Congress on Evolutionary Computation (CEC), pp. 2526-2531, 2015.

[11] B. Vanstone and G. Finnie, "An empirical methodology for developing stockmarket trading systems using artificial neural networks," Expert Systems with Applications 36, pp. 6668-6680, 2009.

[12] L. D. Persio and O. Honchar, "Artificial Neural Networks architectures for stock price prediction: comparisons and applications," International Journal of Circuits, Systems, and Signal Processing, Volume 10, 2016.

[13] D. Enke and S. Amornwattana, "A Hybrid Derivative Trading System Based on Volatility and Return Forecasting," The Engineering Economist, 53, p. 259–292, 2008.

[14] M. Ucar, I. Bayram and A. M. Ozbayoglu, "A Two-level Cascade Evolutionary Computation based Covered Call Trading," Procedia Computer Science, Volume 20, 20, pp. 472-477, 2013.

[15] V. Ramasamy and G. Prabakaran, "Optimal Trading Strategies and Performance of Options at NSE," International Journal of Advance Research 6 (5), pp. 1337-1344, 2018.

[16] I. Gurrib, "The Moving Average Crossover Strategy: Does It Work for the S&P500 Market Index?," Global Review of Accounting and Finance, Vol. 7. No. 1, p. 92–107, 2016.

[17] N. Naik and B. R. Mohan, "Optimal Feature Selection of Technical Indicator and Stock Prediction Using Machine Learning Technique," in Communications in Computer and Information Science, Singapore, 2019.

[18] D. H. Bailey, J. M. Borwein, M. L. d. Prado and . Q. J. Zhu, "Pseudo-Mathematics and Financial Charlatanism: The Effects of Backtest Overfitting on Out-of-Sample Performance," Notices of the American Mathematical Society, vol. 61 No. 5, pp. 458-471, 2014.

Preliminary Study: Electronic Counting in Indonesian National Election Using Computer Answer Sheets and DMR Software

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ABSTRACT

The 2019 election is the most expensive, complicated, and the worst of the 12 elections in Indonesian history. There are 894 election officers' death due to overworking load and it cost the nation 25 trillion Rupiah or about 1.8 billion USD, involved 16 parties, 192.2 million voters, 7.6 million officers, and 810,329 polling stations spreading in 83,405 villages throughout Indonesia. The election was held simultaneously for selecting legislative members and the president, utilized five ballots, and was held one day, including for polling, and counting, making the 2019 elections the most complicated in the world. The time for processing five ballots for voting took about 5-7 minutes on average and another five minutes for counting. Moreover, the ballot tabulation process from polling stations to the national level was manual and took 36 calendar days, adding complexity to the post-election process. This work aims to propose an approach to improve the efficiency and accountability of the voting and tabulation process. Propose to use a single ballot like a computer answer sheet, marked with a regular marker, optical scanned, and finally processed by Digital Mark Reader (DMR) software. The proposal can save 280.7 million square meters of paper use nationally, shorten 80% of voting time to no more than one minute, increase pooling station capacity by 930%, and 8 working hours for officers in. And in the Kapuk-Jakarta Administration Area alone, it can save a budget of Rp 3.4 billion and 38,556 working hours.

CCS CONCEPTS

• **Software and its engineering**; • **Software creation and management**; • **Software verification and validation**;

KEYWORDS

Election, Voting, Optical Scanning, Ballot

*Place the footnote text for the author (if applicable) here.

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1 INTRODUCTION

Indonesia, the third-largest democratic state [1], has conducted 12 times national election since independence from 1955 until 2019. And the 2019 election is the most expensive, complicated (refers to the number of ballots that the voters shall cast at the voting booth, number of parties, and number of candidates each party) [2], and the worst in 12 times election in Indonesian history refers to many victims' election officials died and were sick.

It cost the nation 25 trillion Rupiahs, 16 parties, more than 245 thousand candidates [3], 192.2 million voters, 7.6 million officers, 810,329 polling stations (TPS) spreading in 83,405 villages throughout Indonesia. A poor election system has a big contribution to make the 2019 election is the worst, using 5 ballots with a big dimension and was held one day including for polling and counting. Moreover, the election results also cannot be known quickly, ballot counting and tabulation process (from TPS to the national level) were done manually and took 34 days, adding complexity to the post-election process.

The impact, a lot of hoaxes arose, conspiracy theories emerged in the community, vulnerable to tabulation manipulation [4], all the aspects increased political tension and uncertainty to the public. The indisputable fact of making the worst 2019 election in history is the fall of the victims of election officers, caused by working hours of up to 24 hours non-stop, leading to extreme fatigue. Chief Commissioner of Election Commission (KPU) reported 894 officers' death and 5,175 others suffered a serious illness [5].

With same format, KPU has been proposed a budget of 86.2 trillion Rupiahs for 2024 Election, which almost 3.5 times the 2019 Election, and 44.9% budget for official in operational level like TPS. This became a concern for the House Representative and asked the KPU to recalculate the budget [6]. This study tries to find a new method of voting, counting, and tabulation process that is more efficient, sustainable, transparent, and humane.

1.1 Ballot

There are 5 types of ballots used for voting (except Jakarta Province used 4 types of ballots) to select Presidential candidate, Regional

Figure 1: Five type ballots used for voting, from left to right: Presidential candidate, National legislative (DPR), Provincial legislative (DPRD TK I), City/District legislative (DPRD TK II), and Regional Representative Council (DPD).

Figure 2: Tabulation of the 2019 election vote

Representative Council candidate, and Legislative candidate at various levels (national, province, and city/district) see figure 1. It needs the 1.5852 square meter paper to produce ballot for one voter needed [7].

1.2 Voting Process Flow

TPS is opened at 7 am and closed at 1 pm for voting process then following counting process. There are 7 steps needed for one voter to complete their voting process in TPS [8]. From a simulation report performed by the General Election Commission (KPU) 1 month prior to the election, voters took 3-8 minutes with 5 minutes averagely to punch all five ballots (d). Senior citizens or people with disabilities tend to be longer than young or normal people.

The majoring of respondents felt difficulty opening and fold back all five ballots with the ballot dimension is wider than the voting booth dimension (exclude Presidential ballot). Due to the above reason, KPU set one TPS for 300 voters maximum to reach targetable to finish the whole voting process at 1 pm in following day.

1.3 Tabulation

The tabulation process is started from the ballot-counting process in TPS until the national level in Jakarta. This process took 36 days from 17 April (D-Day) until 22 May (Final Day) as Figure 2 below, it becomes one of the world's longest tabulation processes.

In the TPS, the counting process can be reached to 1-2 am on 18 April (D +1), then continuing with finalizing report and certificate until 3-5 am which prepared for the next tabulation in the Sub-District level. Afterward, officials in TPS delivered all ballots and boxes along with a report to the sub-district office. This exhausting process is finished around 7 – 12 am.

The tabulation process in the Sub-district office is no less tiring with TPS, especially for area in big cities which have a dense and lot of population, automatically have lots of TPS established. For example, Indonesia's biggest number of TPS within one Sub-District is Cakung, East Jakarta, there are 1,461 TPS totally and need to recapitulate one by one manually.

At this stage there is a plenary session which is attended by stakeholders in the election, officers in the sub-district tabulated one by one the election results at the TPS level. They took documents from the box containing the vote count results at one TPS then re-recorded the results manually. If there are no objections from witnesses or those present at the time, then the results at this TPS will be finalized [9]. This process is redone exactly 1,460 times for the rest of TPS in this Cakung Sub-District.

The tabulation is done in the city's level with the same format (plenary session and manually), next in Province level and the last is the National level. This is the end of the election process which the data came from 810,329 TPS spread the whole of Indonesia territory was pushed to KPU in Jakarta manually in multi-stages.

1.4 Cause-Effect Analysis

Based on Indonesian law number 7/2017 article 167 paragraph 3 concerning General Elections, "Voting is held simultaneously on public holidays or days that are closed nationally" [10]. Article 168

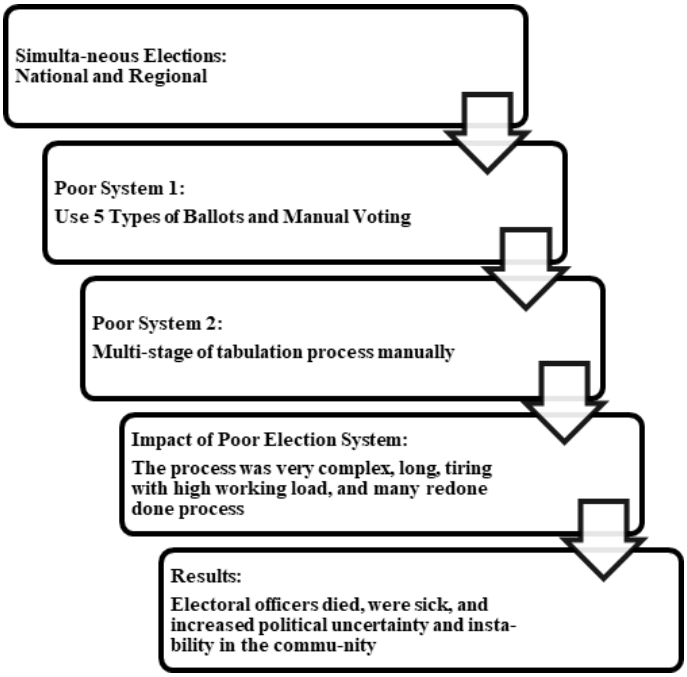

Figure 3: Cause Effect Analysis The 2019 Indonesian Election

states that the General Election is a means of popular sovereignty to elect members of the House of Representatives at the national and regional levels, members of the Regional House of Representatives, the President and Vice President, which are carried out directly, publicly, freely, confidentially, honestly, and fairly. In 2014 the election has two stages, legislative election first then-presidential afterward.

With the simultaneous election, automatically increased working load and pressure to the officers at TPS level. Due to same system used, in 2019 KPU reduced maximum voters in one TPS from 500-600 to 300 voters to balance the working load of 7 officers. Based on actual simulation did by KPU in several areas 1-month prior election (300 voters and well-trained TPS officers), the whole process is finished around 12 pm. In election day, mostly TPS finished it at 2 – 4 am on the following day although with 70 - 85 % voter participation.

Figure 3 illustrated what is the impact of the simultaneous election using the previous system in 2014.

1.5 Election Technologies

Paper ballots have served the election process well. They are relatively easy to produce, easy to mark and easy to count, but they can be quite expensive to print and distribute, they can only be used once, and they are not a particularly good use of resources [12].

Counting paper ballots manually, although relatively reliable can prove to be cumbersome and prone to errors which, in turn can result into the need for multiple counts of the same ballots. The development of cheap, easily delivered, reusable, reliable electronic voting methods may gradually replace the paper ballot in many countries

1.5.1 Electronic Voting. Digital technology brings greater efficiency in many walks of life, and elections are no exception. Online databases hugely facilitate the task of creating and managing accurate and up-to-date electoral rolls. In less developed countries, whose citizens often lack reliable identity documents, biometric technology can help to identify voters, thus preventing fraud in the form of multiple voting [11].

Electronic voting or e-voting is a way to get the people's vote electronically. There are different kinds of electronic voting systems used in several countries around the world. Most of these systems adapt existent technologies or develop specific technologies to be used for electoral purposes [12]. The main types of electronic voting systems include:

1. Punch card voting/tabulation systems, with punch card systems, voters punch holes in cards using a supplied punch device, to indicate votes for their chosen candidates. After voting, the voter may feed the card directly into a computer vote tabulating device at the polling place, or the voter may place the card in a ballot box, which is later transported to a central location for tabulation.
2. Optical scanning systems, an optical scanning device combines specialized computer hardware and software. The hardware devices capture an image and software converts the image to computer-readable data. Voters using machine-readable ballots are given a ballot card with the names of candidates printed on it. Next to each candidate a symbol is printed, such as a rectangle, circle. The voter indicates a choice for a candidate by filling in the appropriate rectangle or circle. After voting, the voter may feed the card directly into a computer vote tabulating device at the polling place, or the voter may place the card in a ballot box, which is later transported to a central location for tabulation. The computer tabulating device identifies the marks made by voters on the cards and records votes accordingly. The individual votes are recorded in a database and aggregated to give total results.
3. Direct recording electronic systems (DRE), using DRE systems, voters mark their votes directly into an electronic device, using a touch screen, push buttons or a similar device. With DRE systems there is no need for paper ballots. Voting data is stored by the electronic device, on a computer hard disk, flash disc, or cloud system etc.
4. Internet, by making electoral participation as easy as logging in to a website, checking a few boxes on a form, and clicking the "Vote" button, it is likely that voter turnout, and hence the overall legitimacy of the results, may be improved significantly. It could also allow significant cost-savings in the deployment and operation of physical polling stations, if the "adoption rate" of internet voting is at a sufficient level. The counting and tabulating of electronic ballots are potentially much faster and easier than counting traditional paper-based or even optical-scan or punch-card ballots, which may represent significant cost savings as well.

1.5.2 Other Countries Experience. Electronic voting machines are used on a large scale in Belgium, Brazil, India, Venezuela, and the United States among others. Although there is a trend for adopting

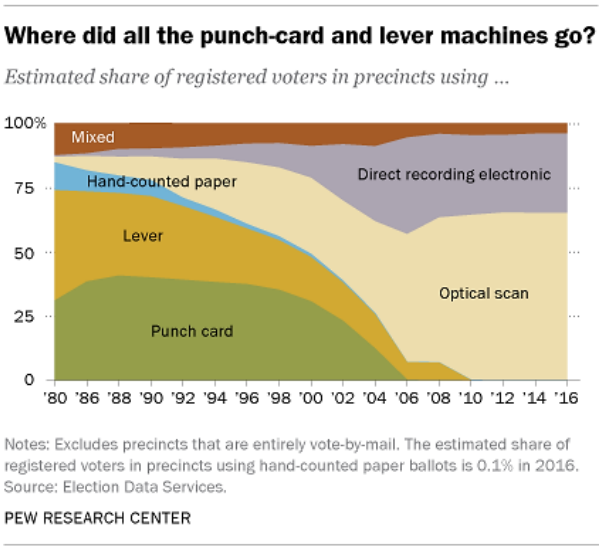

Figure 4: In 2016, on US Election Day, most voters use electronic (DRE) or optical-scan ballots (Pew Research Center)

this technology there are still many countries that prefer hand-marked and manually counted paper ballots like Indonesia.

Electronic voting machines count votes quickly and accurately, in US there are two basic forms of voting technology to record the choices: optical-scan ballots, in which voters fill in bubbles, complete arrows or make other machine-readable marks on paper ballots; or electronic voting machine called as direct-recording electronic (DRE) devices, such as touch screens, that record votes in computer memory [13].

Nearly half of US registered voters (47%) live in jurisdictions that use only optical-scan as their standard voting system, and about 28% live in DRE-only jurisdictions, another 19% of registered voters live in jurisdictions where both optical-scan and DRE systems are in use as figure 4.

However, for some aspects of election management, digitalization is more controversial. Electronic voting machines count votes quickly and accurately. First used in the United States, they have spread to several Latin American and Asian countries. However, the intangible nature of digital processes makes detecting tampering more difficult; as a result, most European countries are sticking to tried-and-trusted conventional paper ballots [14].

Filipina is a successful example for developing countries that left the traditional paper ballot system and moved to an optical scan on the election that has been used nationwide since 2010 which brought President Benigno Aquino III to power, there are more 76,367 counting machines deployed and only 0.6% counting machines were reported as malfunction [15].

Iraq which held Parliamentary Elections on 10 October 2021, has implemented some technologies on election process. Election Commission used of the voter verification device (VVD), the polling count optical scanner (PCOS) and the results transmission device (RTD) [16].

2 METHODS

2.1 Research Question

Research question for improving election process in this preliminary study were:

1. What is a simple and familiar voting technology to be implemented for Indonesian people?
2. How to streamline the process of voting and counting votes and increasing the capacity of the number of voters in one polling station?

2.2 Research Steps

The research began by studying the electoral system used in the 2019 elections. Focus, how to vote, count and recapitulate votes at the polling station and sub-district levels which the most time-consuming process. One of the most critical issues is finding a new ballot format to reduce average transaction time [14].

Step 1 was trying to find a weakness of the election system and looking the room for improvement. We reviewed some election systems implemented by either both developing and developed country. We searched existing technology in the Indonesian market that can be adopted for improving the election system to be more efficient and effective from the current condition.

Step 2, in collaboration with PT. Codena, who holds patent and marketing for DMR software, developed new ballots just like a computer answer sheet with a superior feature, QR Code (see Figure 6). The QR code is a vital feature due to avoid forgery such as double print or double recording when tabulation. QR Code is a key feature to control originality and the number of ballots accordingly. Voters can trace QR Code number in KPU system whether their vote is existed and correctly recorded in the system.

DMR is an application developed at the Laboratory of Graphics and Artificial Intelligence, Bandung Institute of Technology (ITB) Department of Informatics Engineering, leaded by Prof. Dr.Ing.Ir. Iping Supriana, DEA together with the ITB Flagship Research Team in 2002/2003 [17].

This DMR study was originally a digital-themed Optical Mark Recognition (OMR) research by utilizing a low-cost digital document scanner to read the Computer Answer Sheet (CAS). The main challenge of a form that enters the scanner is the occurrence of geometric distortion in the form of shear and rotation which are sometimes invisible to the eye but greatly affect the accuracy of the reading.

With a simple digital image scanner and after undergoing various experiments, the DMR-Extractor was developed, which has a scanning, extraction, and report generation module. To be able to store up to improve image quality so that the readings are accurate, the DMR ITB Development Team also implemented several sophisticated algorithms that allow the reading of all types of CAS, including CAS OMR.

The latest DMR can check up to 12,000 CAS per minute without reducing its accuracy. Besides checking the answers, the DMR is also equipped with an analysis of exam answers and the results of the questionnaire statistics. When using the DMR, participants can use markers or pens when filling out answers, in contrast to OMR which requires the use of 2B pencils in filling CAS. Test

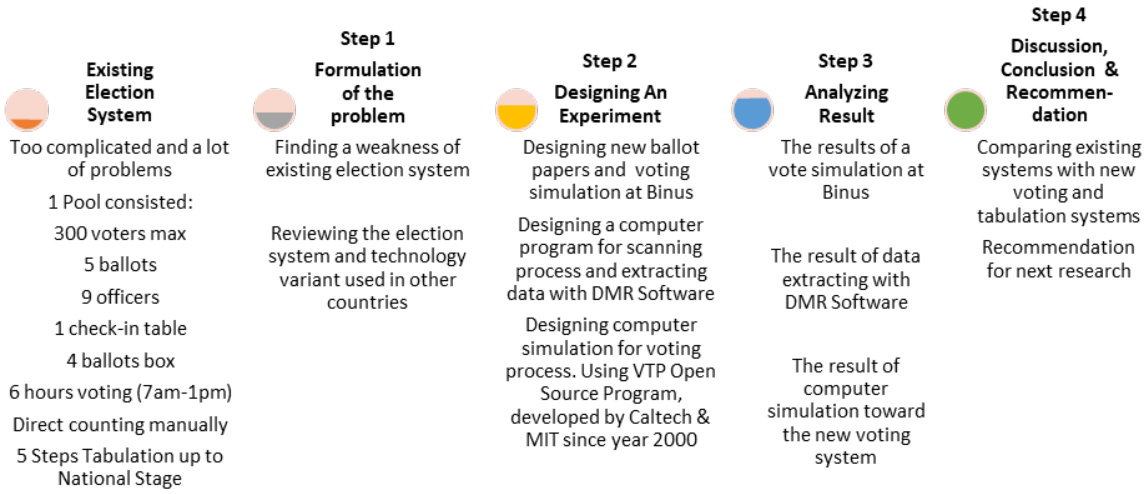

Figure 5: Research method

Figure 6: New ballot paper layout design 0.12474-meter square, the function just like a computer answer sheet. It is a combined 5 type ballot used before. And equipped with QR Code feature to avoid a forgery (double print or double recording)

administrators can use photocopy paper, single-color answer sheets, or even print with a normal printer, the size of the paper is not restricted from A3 to A5.

We performed actual voting simulation and later followed by fifty-one Binus University students, using a new ballot type then scanned and extracted the data by DMR software. After got the data from the actual simulation, we did computer simulation using an open-source program using queuing theory from Voting Technology Project (VTP) which developed by the California Institute of Technology (Caltech) and Massachusetts Institute of Technology (MIT) [18].

This computer simulation has a purpose to look any possibility merged some TPS due to ballot issue has been improved and more efficient.

Table 1: N, Mean, Mode, Modus, and STDEV

N	Mean	Mode	Modus	STDEV
51	43.2 Sec	45 Sec	44 Sec	8.9

Using one of The Election Management Toolkit provided ("Line Optimization"), simulation process is run 1,000 times and set some assumption as follows:

1. The number of voters in one TPS is 2800 (ten times of average voters' number in Jakarta).
2. TPS is performed voting only while counting and tabulation will be centralized in one area.
3. Average minutes to check-in and vote set is 1 minute each.
4. The poll is opened at 7 am and closed at 3 pm (8 hours).
5. Arrival pattern is Mid-Morning Peak with random based arrival.
6. Early arrival 1.2%, voters cannot check-in 2.0%.
7. Check-in desk 7 unit, voting station 7 unit.

Step 3, analyzing experiment result from step 2, Step 4 made a discussion, conclusion, and recommendation for the next research.

3 RESULT AND DISCUSSION

3.1 Actual Voting Simulation

Mean voting simulation is 43.2 second, for computer simulation rounded to 1.0 minute (considering efficiency reach 75% only) see table 1.

3.2 Computer Voting Simulation

Based on the simulation, the longest average waiting time occurred at 10.15 was 7 minutes totally (check-in 7 minutes and voting 0 minutes), and there are no voters on the queue that will be projected walk-offs (cancel to vote due to facing long queuing). In theory, voters took 9 minutes only (include check-in and voting time) to finish the voting process from arrival until coming out from TPS.

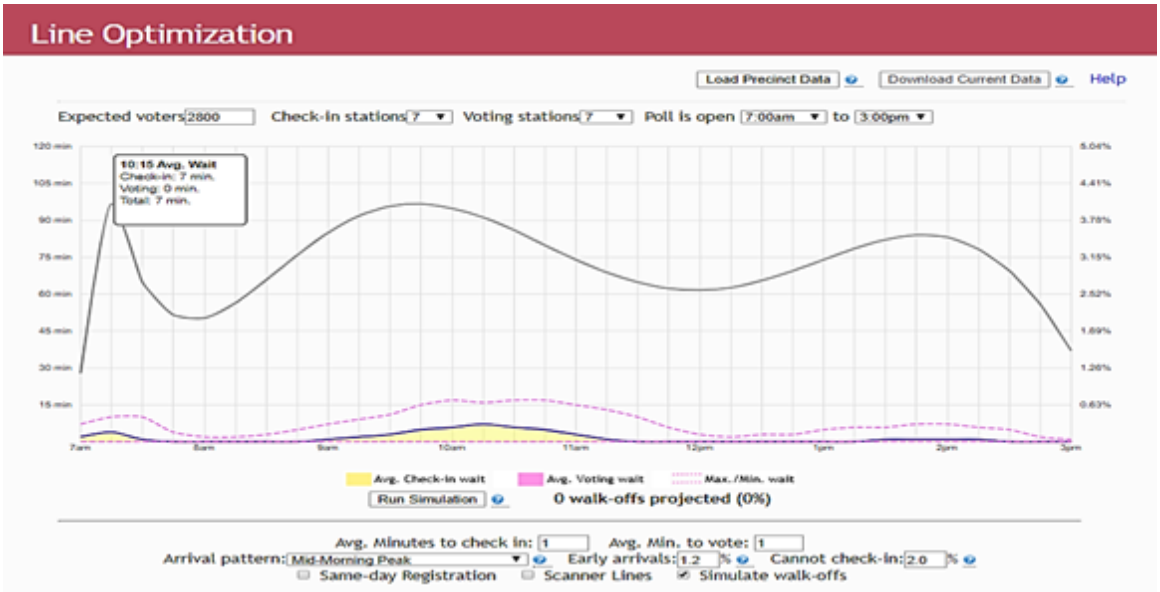

Figure 7: Voting computer simulation result. Using VTP-MIT/ CalTech open resource program.

This is far below the US upper limit standard which targeting voters in TPS are 30 minutes maximum [18].

3.3 Ballot Scanning and Extraction Result

All fifty-one ballots can be scanned and extracted with a Fujitsu 7140 scanner at a speed of 40 ballots per minute. By setting the scan quality to DPI 100, it can produce clear black/white images of only around 200 kb (Figure 8).

One ballot with QR Code # 123464 is "error" and cannot be extracted the data and tabulated due to voters give thick marking for both presidential candidates instead of one as figure 9 below.

3.4 Discussion

There are some key findings base on research question made for this study:

What is a simple and familiar voting technology for Indonesian people? From four voting technology, the suitable technology is Optical Scanning System due to following reason:

1. Tens of millions of Indonesians are already familiar with the format of this ballot, like a computer answer sheet when they take the national final exam at various levels of education, starting at the elementary level (since year 2009) [20], Junior High School (since year 2006) [21], Senior High School, and University entrance selection.
2. No using expensive and special machine-like DRE System, Optical system using generic high speed scanning machine and can be used after election.
3. The DMR software was made by an Indonesian engineer, the scan results are in the form of images and can be audited with all parties participating in the election.
4. A voter can see the tabulation results of his ballots, because each ballot has an individual number that is stored in the QR Code.
5. The national tabulation process can be started from central counting through the internet network. Based on 2020 data, there are 84,038 villages / administrative areas nationally, 93.21% of areas can receive a cell phone signal; 72.65% have a strong signal, 20.56% have a weak signal, and only 6.79% without a signal [22]. This data will improve gradually until 2024.

How do streamline the process of voting and counting votes and increase the capacity of the number of voters in one polling station?

1. Redesigned ballots from five sheets to one sheet, saving 280.7 million square meters of paper nationally.
2. From simulation it takes less than one minute to cast a ballot instead of 5 minutes previously (reduced by 80%).
3. Ballot counting process uses a high-speed scan machine that can be placed at the TPS, or ballot is transported to a central location for counting and tabulation.
4. From simulation, one polling station capacity increased and able to serve 2800 voters (increased by 930%) with 14 officers.
5. As case study, if we take Kapuk Administrative, Cengkareng Sub-District, West Jakarta has 400 TPS totally to serve 104,710 voters in 2019 Election. With the new system it needs 38 TPS only (reduced by 90.5%). The number of TPS officers in Kapuk can be drastically reduced, from 2,800 to 532 officers (81% reduction).
6. In the 2024 election, the KPU estimates that one officer will receive an honorarium of Rp. 1.5 million. The reduction of 2,268 officers in the Kapuk area alone will save the budget at the TPS level by Rp. 3.4 billion and 38,556 working hours.

Figure 8: Ballot scanning in color version

Figure 9: Error data due to voters put thick marking for both Presidential candidate

3.5 Future Research

This preliminary study shows the great potential of the implementation of e-voting in Indonesian elections, and requires further studies, including:

1. It is highly recommended to conduct pilot project to scale up this method prior to implementing in 2024 Election.
2. If counting and tabulating are being centralized, it is recommended to set a protocol on how to deliver ballots to the counting center to keep the integrity of election results.

4 CONCLUSION

This study aims to improve the voting, counting and tabulation process of the National Election, which is more humane, sustainable, simple, concise, transparent, and low cost. Redesigning ballots, and using electronic counting and tabulation methods, are the key to improving Indonesia's overall electoral system.

This study proposed one paper ballot with a QR code feature to replace the existing five paper ballots, the results are reducing 280.7 million square meters of paper consumption nationally, the average voting vote time from 5 minutes to below 1 minute. Using a new

type of ballot, computer simulation results show that one polling station can accommodate 2,800 voters (930% the current number) with an average waiting time of 7 minutes. Election officers working hour is set for 8 hours, not 17-20 working hours as 2019 election which caused 894 officers were death.

For counting and tabulation, manual and multi-stage processes are replaced with electronic by using scanners and DMR software, the scanner can process 2,400 ballots/hours and tabulate it automatically in one stage. Currently electronic transmission data is possible nationally due to 93.21% of total villages / administrative areas has been internet signals.

Significant reductions in polling time and dramatic increases in polling station capacity will result in a significant reduction in the number of polling stations and TPS officers. That will have a significant impact by saving Rp 3.4 billion budget and 38,556 working hours in Kapuk Administrative only.

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REFERENCES

[1] Lestari, M., Asikin, Z., & Risnain, M., Presidential Threshold Concept in the Democratic Perspective in Indonesia, International Journal of Scientific Research and Management, 7(06), 149-150, 2019.

[2] Yoga, S., Jusuf Kalla: The 2019 Election Will Be The Most Complicated Election In The World, Kompas.com, https://nasional.kompas.com/read/2018/06/25/15183661/jusuf-kalla-pemilu-2019-akan-jadi-pemilu-terumit-di-dunia (25 June 2018).

[3] Ben, B., Indonesia's Incredible Elections: Why Indonesian elections are unlike any other in the world, Lowy Institute, https://interactives.lowyinstitute.org/features/indonesia-votes-2019/ (7 January 2020).

[4] Rakhman, S., Evaluation of 2019 election tabulation result (Case study of Cengkareng Sub-District), AIPI XXVIII National Seminar, 2019.

[5] Sania, M., Reflection on the 2019 Election, 894 KPPS Officers Died, Kompas.com, https://nasional.kompas.com/read/2020/01/22/15460191/refleksi-pemilu-2019-sebanyak-894-petugas-kpps-meninggal-dunia (22 Jan 2020).

[6] Rezza, A. P., 2024 Election Budget Too Big, KPU Will Try Rationalization, Katadata.co.id, https://katadata.co.id/rezzaaji/berita/6149593534b1c/anggaran-pemilu-2024-terlalu-besar-kpu-akan-coba-rasionalisasi (21 September 2021)

[7] KPU Sumenep, 2019 Election Ballot Specimen, http://kpud-sumenepkab.go.id/spesimen-surat-suara-pemilu-2019/ (12 December 2019).

[8] Sekretaris Jenderal KPU, KPPS Guide: Voting and Counting Votes for the 2019 General Election, KPU, http://perludem.org/wp-content/plugins/download-attachments/includes/download.php?id=4659 (10 December 2019).

[9] Sekretaris Jenderal KPU, PPK Guide: Tabulation of Vote Count Results at the Sub-District Level, KPU, http://perludem.org/wp-content/plugins/download-attachments/includes/download.php?id=4662 (10 December 2019).

[10] Peraturan.go.id, State Gazette of The Republic No.182, 2017Law of The Republic of Indonesia Number 7 of 2017 Concerning General Elections, https://peraturan.go.id/common/dokumen/ln/2017/uu7-2017bt.pdf (December 2019).

[11] Martin, R and Ionel, Z., Digital technology in elections: Efficiency versus credibility?, European Parliament Research Service, https://www.europarl.europa.eu/RegData/etudes/BRIE/2018/625178/EPRS_BRI(2018)625178_EN.pdf (2018).

[12] The ACE Electoral Knowledge Network., Elections and Technology, Ace Project, https://aceproject.org/ace-en/topics/et/eth/eth02/eth02b/default ,(2022).

[13] Drew D., On Election Day, most voters use electronic or optical-scan ballots, Pew Research, https://www.pewresearch.org/fact-tank/2016/11/08/on-election-day-most-voters-use-electronic-or-optical-scan-ballots/ (8 November 2016).

[14] Stewart III, C., & Ansolabehere, S., Waiting to vote Election, Law Journal, 14(1), 47-53, 2015.

[15] Filipinas Heritage Library, A History of automated elections in the Philippines, https://www.filipinaslibrary.org.ph/articles/a-history-of-automated-elections-in-the-philippines/ (15 December 2019).

[16] Election Observation Mission to Iraq 2021, EU EOM Iraq 2021 Preliminary statement, European Union Election Observation Mission to Iraq 2021, https://eeas.europa.eu/election-observation-missions/eom-iraq-2021/105451/eu-eom-iraq-2021-preliminary-statement_en (12 October 2021).

[17] Hafshah, N. A., Digital Mark Reader, ITB's Phenomenal Work for the Best Examination Technology, Institut Teknologi Bandung, https://www.itb.ac.id/news/3845.xhtml (28 February 2013).

[18] Stephen, G and Rong, Y., VTP Toolkit: Line Optimization and Poll Worker Management, Voting Technology Project Caltech / MIT, http://web.mit.edu/vtp/index.html#articles (2016).

[19] Stein, R. M., Mann, C., Stewart III, C., Birenbaum, Z., Fung, A., Greenberg, J., ... & Beaulieu, E., Waiting to Vote in the 2016 Presidential Election: Evidence from a Multi-county Study, Political Research Quarterly, 1065912919832374, 2019.

[20] Mahsusi, Press Release: Ujian Nasional (UN) untuk MTs dan MA Ujian Akhir Madrasah Berstandar Nasional (UAMBN) untuk MI Tahun Pelajaran 2008/2009, https://2017.kemenag.go.id/file/dokumen/PressReleaseUNdiMadrasah.pdf, (17 April 2009)

[21] Bambang, S., The Ministry of National Education, MINISTER OF NATIONAL EDUCATION OF THE REPUBLIC OF INDONESIA NUMBER 20 OF 2005 CONCERNING THE NATIONAL EXAM FOR THE ACADEMIC YEAR 2005/2006 https://jdih.kemdikbud.go.id/arsip/permen_tahun2005_nomor20.pdf, 13 October 2005.

[22] Tri, S, *et al*, Telecommunication Statistics in Indonesia 2020, Catalog:8305002, Directorate of Financial, Information Technology, and Tourism Statistics BPS-Statistics Indonesia, Jakarta, October 2021.

mHealth Apps Interface Concept Design Using Meta-Principle

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ABSTRACT

In line with the recent development of technology, various access to health can be done through smartphones. Many developers are looking for profit by making mHealth applications, especially during the Covid-19 pandemic. However, the display features in these apps have not used ergonomic design principles. Therefore, this study aims to design an ergonomic interface design concept for mHealth apps. The method used refers to the meta-principle for designing digital applications.

The initial stage was carried out by distributing online questionnaires to identify user needs. The second stage is benchmarking which is done by evaluating the interfaces of the 4 existing mHealth applications. The next step is to develop the meta-principles needed to design the interface for the mHealth application.

The final result of this study is an interface design concept for mHealth apps which is obtained by combining user needs data, benchmarking evaluation and meta-principles. The design concept consists of the top, middle and bottom part of application displays.

CCS CONCEPTS

• **Human Computer Interaction**; • **Usability**; • **User needs**; • **Meta-principle**;

KEYWORDS

mHealth, interface, meta-principle design

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1 INTRODUCTION

In 2021, there was a delta variant of the Covid-19 case which was first detected in India and then spread throughout the world, including Indonesia [1]. With more than 49,000 confirmed cases by mid-year, Indonesia has turned into the main epicenter of the Covid-19 pandemic [2]. This second wave of positive Covid-19 cases in Indonesia has had a major impact, including a high mortality rate [3]. It is confirmed that the number of deaths due to Covid-19 in Indonesia is more than 1,300 in a day and among them, hundreds of people died while undergoing self-isolation [3]. This is because several hospitals have collapsed, thus refusing Covid-19 patients [2]. Lack of availability of drugs and oxygen is also a contributing factor [4]. Therefore, many Covid-19 patients are forced to self-isolate at home. Without doctor's supervision, patients in self-isolation face many obstacles, such as access to medicines that require a doctor's prescription.

Referring to this case, it is necessary to have a digital health application that can support patients when doing self-isolation at home. Even though the number of Covid-19 cases has decreased, designing apps like this is important when a pandemic of another disease spreads. Currently in Indonesia, various mHealth apps have been developed such as Halodoc, Alodokter, Klikdokter, etc. Several studies were conducted on Halodoc as the most popular digital health applications in Indonesia [5] [6], but the results show that usability issues are still found in this application, one of which is related to visibility of system status. Another study [7] also compared the Halodoc application with Alodokter, Klikdokter, each of which showed the same results. The weakness of these applications can certainly make it difficult for users, especially self-isolated patients or outpatients.

Therefore, this study aims to develop the mHealth apps interface design concept using meta-principles. Meta-principles are visual design characteristics that are chosen by application designers to convey language to users which consist of consistency, hierarchy and personality [8]. This meta-principle also focuses on designing the visual appearance of the application. This design concept is expected to help mHealth apps developers to design ergonomic applications that can make it easier for users.

2 INSERTING CONTENT ELEMENTS

Initial data collection is done by distributing user needs identification questionnaires. The questionnaire data was collected by using judgment sampling technique using an online questionnaire from google form. Based on the results of the initial questionnaire distribution, 70 respondent data were obtained with the target being respondents who had used the mHealth application and or had experienced/accompanied Covid-19 patients. The distribution of respondents shows that the number of male and female respondents is almost the same, namely 52.9% and 47.1%, but the respondents are dominated by the age range of 18-35 years. A total of 24.2% of respondents stated that they had never used mHealth apps while the rest had used it and Halodoc was the most used application with a percentage of 74.2%. On average, 30.2% of respondents have used mHealth apps for more than 6 months. This questionnaire also consists of 5 questions to identify user requirement needs as input for the mHealth apps interface design concept.

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The second stage is benchmarking, which is done by evaluating the existing mHealth apps interface through identifying the strengths and weaknesses of the application. The mHealth applications are Halodoc, KlikDokter, Aidohealth, SehatQ. Strengths in the application serve as input references to the design meta principle, while weaknesses serve as guidelines for avoiding the same error or correcting the error.

The meta principle design method is used in this study because it relates to the usability principle for designing an application consisting of consistency, hierarchy and personality. The meta principle design that has been compiled consists of 23 rules. Finally, formulate a design concept by combining user needs data based on the results of the questionnaire, strengths and weaknesses based on the evaluation results of the existing mHealth apps interface and the rules of the meta principle design.

3 RESULTS

3.1 User Needs

This user needs questionnaire section consists of 5 questions. The results of the first question indicate that 95.7% of respondents agree with the design of this ergonomic mHealth apps interface. The second question relates to the design desired by the respondents regarding the mHealth application and consists of open answers and 4 closed answer choices, namely (1) the application is easy to use, (2) the information is easy to understand, (3) has complete features, (4) attractive display design. The results showed that there were 5 open answers given by the respondents. As input, 4 open answers will be considered that are still related to the design of mHealth apps, namely a comfortable user experience, psychological services, 24-hour service and payment channel integration, while the other 1 answer is outside the purpose of designing the mHealth application. All answer choices provided have a presentation above 50%. This shows that respondents want an application design that uses the usability principle. The highest number is the need for easy-to-use applications as much as 91.4% because this is the main factor in usability design principles while the lowest number is in attractive display designs with a percentage of 55.7% which indicates that respondents are more focused on content than appearance.

The third question relates to the features desired by the respondents. Doctor consultations and medicine purchases are the most desirable features with a percentage of 92.9% and 88.6%, respectively, this is because these 2 features are the main features needed. Other features that respondents want are PCR or rapid antigen 85.7% services; emergency calls 78.6%; oxygen availability 78.6%; availability of hospital rooms 75.7%; medical equipment rental 70%; the location of the nearest pharmacy 70%; and catering services for self-isolated patients or outpatient 52.9%.

The color theme in the mHealth application that the respondent wants in the fourth question shows that the color that is comfortable for the eyes is the highest choice of the respondent with a percentage of 88.6% while the lowest percentage is the choice of a colorful theme. This shows that most of the respondents have indirectly chosen a color theme according to the meta-principle method, while the colorful theme is a color that should be avoided because the theme removes the focus on application content and makes the eyes uncomfortable. The last question relates to the suggested

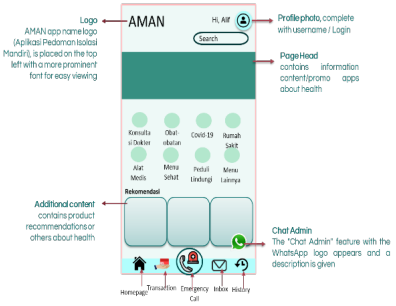


Figure 1: Design Concept of AMAN Apps

name for the mHealth apps that will be proposed in this study, namely - in bahasa- AMAN (Aplikasi Pedoman Isolasi Mandiri) with a percentage of 44.3%.

3.2 Benchmarking mHealth apps

Benchmarking is done by evaluating the current design of mHealth apps. This stage can be used as a reference at the stage of formulating a design concept regarding what usability criteria, elements or principles already exist in the design of mHealth apps on the market today. Benchmarking was carried out on 4 mHealth apps with a rating above 4.0 on the Google Play Store as in the questionnaire data collection stage that was carried out. The strengths and weaknesses of each application at this benchmark stage are determined based on whether or not usability principles have been implemented in the application. The results of the benchmarking stage of mHealth apps are presented in Table 1.

3.3 Meta Principle Design

After obtaining the user requirements needs data from the questionnaire as well as the strengths and weaknesses of the existing mHealth apps, the next step is to describe the rules of the meta principle design as input for the mHealth apps interface design concept. The meta principle design rules are related to usability principles for designing an application consisting of consistency, hierarchy and personality. This method focuses on what the user sees, and how to design the app to make it easy to understand. The purpose of this method is to help design complex application interfaces by defining design decisions based on heuristics, usability, perceptual psychology, web design, typography practice, visual design principles, and communication theory [8]. Table 2 presents the rules of the meta principle design.

3.4 Design Concept Formulation

User needs data is based on the results of the questionnaire, strengths and weaknesses based on the evaluation results of the existing mHealth apps interface and the rules of the meta principle design that have been compiled as input in the formulation of the design concept. In formulating the design concept, part of the application interface will be divided into three parts, namely the top, middle and bottom. Table 3 presents the formulation of the design concept.

Table 1: Benchmarking mHealth Apps

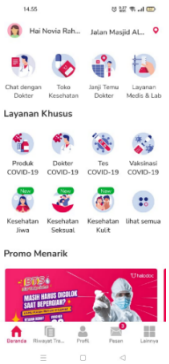
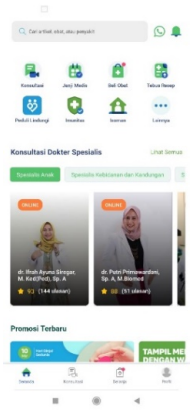
No	mHealth apps	Evaluation
1.		Strength - There is a special service menu for Covid-19 - Easy-to-read and consistent font types - Grid/alignment has been arranged consistently - There is a white space area Weakness - There are no logo and page head on the homepage - Menu's are not grouped by similarity - There is no search term menu - Does not use a color hierarchy to distinguish menu types - The overall appearance of the interface does not represent the characteristics of the Halodoc application
2		Strength - There is a logo and page head on the homepage - Easy-to-read and consistent font types - Grid/alignment has been arranged consistently. - There is a white space area Weakness - There is no logotype to attract users so that the homepage looks monotonous - Few and incomplete features and menus - Menus are not grouped by similarity - No color hierarchy
3		Strength - Colorful homepage display - Has the "Regular Chat" feature that will be connected to the doctor quickly. - There is a WhatsApp feature to contact customer service - Can make medical appointments with nearby clinics and hospitals - Has a Redeem prescription feature, which is ordering medicine by uploading a photo of a doctor's prescription - Easy-to-read and consistent font types - Grid/alignment has been arranged consistently, - There is a white space area - There is a search term menu Weakness - No logo and page head on the homepage - Menus are not grouped by similarity
4		Strength - Provides access to the nearest Clinics and Hospitals. - Interactive and attractive homepage display - Has a Video Chat feature in online consultation - There is information on the rating of health facilities - Easy-to-read and consistent font types - There is a white space area - There is a search term menu - There is a logo and page head on the homepage Weakness -The homepage content is too full -Menu on the homepage is not complete

Table 2: Meta Principle Design

Design Principles		Rules
Consistency	Layout	Screens displaying the same type of information must have all elements positioned the same way Different elements that are related to each other must maintain their spatial relationship. For example, in e-commerce apps, the product name should always be placed in a consistent position relative to the product image.
	Typography	Typographic standards (font type, size and color) are based on the importance level of information
	Color	Use a color palette with primary, secondary, and accent colors to help direct the brain by grouping elements of the same color. It also helps determine the level of importance of information.
	Imagery	Consistency in the use of icons, the creation of new icons must be accompanied by text, while icons that are easy to understand such as question marks do not need to be added with text. Consistency in the use of the logo, both in terms of design and position. Consistency in the use of charts/charts.
	Controls	Consistency in the use of buttons and links, drag-and-drop selection, fades and flips
Hierarchy	Contrast	Creates a visual contrast between elements to make them easier to find and stand out from the rest
	Position	Proximity: The same elements are placed close together so that they appear as a group. The perception of the hierarchy is influenced by how close the elements are to each other. Eye behavior: Most users look at the top left of the interface page when reading, so it is necessary to place the most important elements in this section. Nesting: Placing some elements inside other elements makes the "parent" element appear to be on a higher and more important level Overlap: An element that is placed “above” another element indicates that it stands out more. Lightboxes and popups are common examples of using overlap to grab attention and create a visual hierarchy.
	Treatment	Size: A larger element, or a large group of elements, appears to be more important than similar smaller elements Color: On a light background, dark colors show as more important elements. Warm colors, such as red, yellow, and orange, appear more prominent and saturated, or purer, more eye-catching than dull ones. The use of ornaments can create a contrast with plain elements and signify that the elements are important Gradations can attract more attention and show the level of importance
Hierarchy	Element	Using the necessary elements based on the user persona hierarchy, which is related to the user’s goals and motivations for using the application. For example, the list of elements is arranged with the level of importance starting from the logo/identity, search box, etc.
	Screen Patterns	The screen pattern starts from the top by placing the application level (e.g. logo, search term), followed by a screen level consisting of application content
Personality	Element	Elements using the principles of classic aesthetic quality (related to the organization and symmetry of the arrangement of elements in the application) and/or using expressive aesthetic qualities (related to design harmony, color harmony, dynamic expression in the application).
	Visual Design	Visual characteristics can be expressed through logos, photos, icons, and colors. Use familiar controls for user convenience

Table 3: Design Concept Formulation

Interface	Design Concept
Top page	***Page Head*** a. *Rules*: page head is an important element in a web/apps b. *User needs*: avoid colorful themes c. *Benchmarking*: Of the 4 apps, only AidoHealth and SehatQ already use page heads. Example that can be taken is SehatQ. The page head from SehatQ is the most interesting because it uses a light color palette. ***Logo*** a. Rules: the logo is placed on the top left because users will start looking from the top left b. User needs: the logo of the application name is AMAN with a larger font size and below it (Aplikasi Pedoman Isolasi Mandiri) with a smaller font. On the left side of the logo, a safeguard symbol will be added to make it more attractive. c. Benchmarking: Only 2 applications that have used the logo, namely AidoHealth and SehatQ. Example that can be taken is SehatQ because the logo is more interesting because it applies the principle of similarity and uses application symbols, while AidoHealth only uses a monotone written logo. **Login account** a. *Rules*: consistency with similar previous applications. The icon for the account is symbolized by the person plus the explanatory text. b. *User needs*: easy to use and understand c. *Benchmarking*: All apps provide a user profile menu and are placed at the bottom of the homepage except SehatQ on the top right. In addition, Halodoc has also added the user's name at the top left as a form of greeting. This feature can serve as an example. **Search term** a. *Rules*: search term is an important element that should be placed at the top of the homepage b. *User needs*: easy to use and understand c. *Benchmarking*: Halodoc is the only application that does not have a search menu, while AidoHealth puts this menu at the bottom with a magnifying glass icon. The location of this icon is not prominent so users will have difficulty finding it. Examples that can be taken are SehatQ dan KlikDokter.
Middle page	**Features/Ikon** a. *Rules*: features/icons that are in the same group are brought together by the principle of proximity and/or grouped consistently. b. *User needs*: doctor consultation; medicines purchases; PCR or rapid antigen services; emergency calls; oxygen availability; availability of hospital rooms; medical equipment rental; the location of the nearest pharmacy; and catering services for self-isolated patients or outpatient c. *Benchmarking*: SehatQ has grouped its features/icons
Bottom page	**Additional features/icons** a. *Rules*: additional elements such as home page icons and help feature b. *User needs*: full features and emergency features c. *Benchmarking*: SehatQ is the only 1 that doesn't have an additional feature at the bottom of the homepage while AidoHealth is the only one that has a help feature.

Figure 1 presents the results of the formulation of the design concept that has been made based on Table 3. The results of this design concept are expected to be a reference for designing and or developing an ergonomic mHealth application so that it can make it easier for users.

4 CONCLUSION

Based on the results of the questionnaire distribution, user needs data was obtained which consisted of needs related to design usability, required features, display color themes and application names. Benchmarking analysis is carried out by identifying the strengths and weaknesses of existing applications. Strengths in the application will be an input reference to the design meta principle, while weakness in the application becomes a guideline to avoid the same error or fix the error. Meanwhile, the meta principle design rules are used in this study because they relate to the usability principle for designing an application consisting of consistency, hierarchy and personality. The meta principle design that has been compiled consists of 23 rules.

This study has limitations because it only reached the stage of formulating the design concept. Future research is expected to be

able to implement this design concept into an interface prototype for mHealth apps.

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REFERENCES

[1] BBC News. 2021. Covid: Delta variant spreads globally as cases soar. https://www.bbc.com/news/world-57907681 [accessed 20 September 2021]

[2] National Geographic. 2021. Indonesia is a new COVID-19 epicenter. The peak has yet to come. https://www.nationalgeographic.com/history/article/indonesia-is-new-covid-epicenter-but-the-peak-has-yet-to-come [accessed 20 September 2021]

[3] Satuan Tugas Penanganan Covid-19 Indonesia. 2021. Indonesia fights back the covid-19 second wave. https://covid19.go.id/p/berita/indonesia-fights-back-covid-19-second-wave [accessed 20 September 2021]

[4] Kompas. 2021. Ribuan Pasien Covid-19 Meninggal Saat Isolasi Mandiri, Apa Sebabnya? https://megapolitan.kompas.com/read/2021/07/23/08241841/ribuan-pasien-covid-19-meninggal-saat-isolasi-mandiri-apa-sebabnya?page=all [accessed 20 September 2021]

[5] Arfika Nurhudatiana and Jae Young Seo. 2020. An mHealth Application Redesign based on Nielsen's Usability Heuristics: A Case Study of Halodoc. ICEBA 2020, February 25–27, 2020, Kuala Lumpur, Malaysia. https://doi.org/10.1145/3387263.3387267

[6] M. A. Kushendriawan, H. B. Santoso, P. O. Hadi Putra & M. Schrepp. 2021. Evaluating User Experience of a Mobile Health Application 'Halodoc' using User Experience Questionnaire and Usability Testing. Jurnal Sistem Informasi (Journal of Information System), Volume 17, Issue 1.

[7] Maman Surahman, Nur Widiyasono, Rohmat Gunawan. 2021. Analisis Usability dan User Experience Aplikasi Konsultasi Kesehetan Online Menggunakan System Usability Scale Dan User Experience Questionnaire. Jurnal Siliwangi Vol.7. No.1, 2021 Seri Sains dan Teknologi.

[8] Tania Schlatter and Deborah Levinson. 2013. Visual usability: principles and practices for designing digital applications. Massachusetts: Morgan Kaufmann.

PASPORUMKM ONLINE PLATFORM DEVELOPMENT FOR SELF-GUIDED HALAL ASSURANCE SYSTEM PREPARATION ON THE CASE OF SMES IN THE FOOD SECTOR

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ABSTRACT

UMKM covers around 98% of the total business in Indonesia. From the entirety of the UMKM, food processing is among the top 3 of the total demographics. Additionally, in 2014 Indonesian government has created a regulation of Law No. 33/2014 in which stated that all products that are regulating in Indonesian market must have Halal certification and the government will create a transition time for UMKM to be able to apply Halal certificate for their product. This creates an urgency for the UMKM to fulfill the requirements needed to be able to reach Indonesian market. PasporUMKM is a digital platform providing UMKM for their needs to prepare for the documents of halal assurance systems. This system would digitalize the input of the documents according to Indonesian halal assurance system. Consequently, the UMKM can understand and be assisted to fulfill the requirements. The first prototype was created and tested using user acceptance test to test mainly the functionality and interface of the system. It received a positive result with some feedbacks and evaluations to consider.

CCS CONCEPTS

• **Computer systems organization** → Architectures; • **Information systems** → Data management systems; World Wide Web.

KEYWORDS

Digital Platform, Cloud Service, SME, Halal Assurance System

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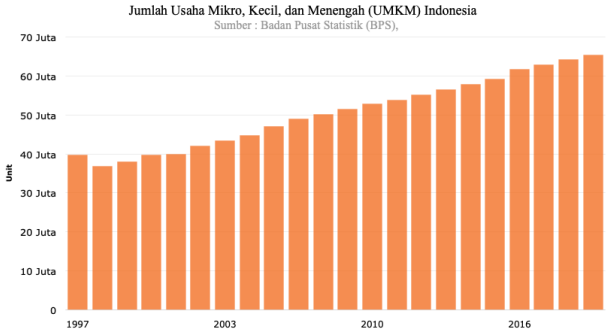

Figure 1: Total of UMKM in Indonesia from 1979 to 2019

Table 1: Amount of UMKM in Indonesia from 2018-2019

Business Unit	Unit	Percentage
Micro Business	63.350.222	98.68%
Small Business	783.132	1.22%
Medium Business	60.702	0.09%
Large Business	5.550	0.01%
Total	64.194.056	100%

1 INTRODUCTION

Usaha Mikro Kecil Menengah in Indonesia (UMKM) is a business activity that is run by an individual, household, or a small business entity.

As can be seen in 1, in Indonesia alone, the number of UMKM is increasing throughout the year and in 2019 the number reached the maximum of 65 million units. It means that the sector is promising with a stable improvement each year.

According to statistic from 1, Usaha Mikro covers almost the entire industry of the business, and they have specific problems that prevent them from growing. Additionally, Government Regulations No. 23/2018 explained that UMKM will be given lower tax incentives for the taxation of 0.5% on the final tariff of the Income Tax or Pajak Penghasilan (PPh) in Indonesian. This means that the business is an attractive market in which the government fully supports with its program. However, there are several problems that are holding them back.

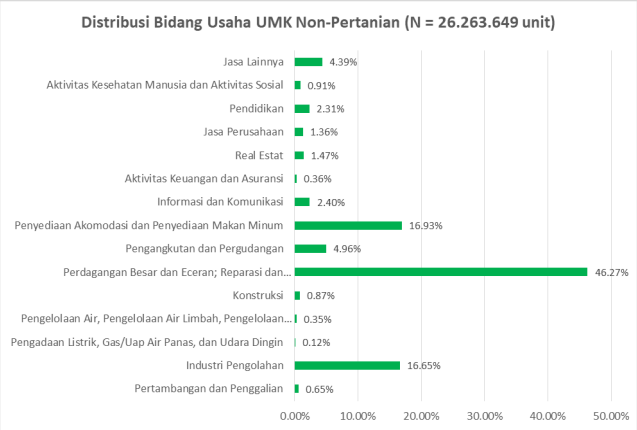

Figure 2: Distribution of SMEs Business for Non-Agriculture 2016

In the large market of UMKM industry, there are a wide range of business types. Based on the data shown from UMKM Indonesia in 2016 in Figure 2, the industry of UMKM in Processing including food processing lies in the top 3 positions with the coverage of 16.65% of 26.263.549 total units. This implies that processing specifically in the food industry has a huge opportunity as a market.

Additionally, in 2014, the Indonesian Government proposed and legalized a new regulation namely Law No. 33/2014 about Halal Product Guarantee in which was operated effectively from October 2019 and the transition phase for the UMKM will be helped for the certification by the government until 2024. The content of the regulation explained that the products that will be regulated in Indonesia are required to have the certification halal and the products that are not halal certified can be put on a prison charge. In addition, to help the UMKM to sustain from the regulation, the government create a transition phase in which the first phase being conducted for the processed food and beverages alongside with the service in the industry as for the phase, it varies among the type of the business until 2024.

This creates an urgency in which the UMKM Industry needs to oblige the regulations with the proper official requirements.

To support the urgency for the UMKM to be able to get the certification, the government create an additional way through Halal Product Assurance System. In [2] This system consisted of 24 different categories of halal products related to processed food and beverage that the government need to monitor. Each of these categories consisted of 11 critical points inside the halal assurance product system that needs to be achieved to continue the halal status with consistency. Consequently, the complexity provided in the system remains high for the UMK to understand.

Based on [5], Self-declare halal certification is a service provided for UMK that has fulfilled certain main requirements and such as:

- Products that have no risk that use ingredients that already have halal certification
- Simple production process according to the halal system

Additionally, through self-declare method, the UMK can get the halal certification without having to send all the documents for the first year. However, they need to provide the documents needed during auditing process to maintain their halal status. This act as a proof from the government about the complexity of the system.

Additionally, in [4], it is explained that the government also takes no fee for the UMK in self-declare to encourage UMK to be able to register their products.

2 LITERATURE REVIEW

2.1 Peraturan Pemerintah No. 7 Tahun 2021 tentang UMKM

In Peraturan Pemerintah No. 7 Tahun 2021 Pasal 35 Ayat 3 [6], it is explained that UMKM is categorized based on several criteria. Firstly, Usaha Mikro is a business that acquired a capital up to 1.000.000.000,00 (1 billion Rupiah), Usaha Kecil has the capital from Rp. 1.000.000,00 to Rp. 5.000.000.000,00 not including the land and buildings. Lastly, Usaha Menengah is a business that has capital from Rp. 5.000.000.000,00 to Rp. 10.000.000.000,00 not including the land and buildings.

2.2 Brief Concept of UMKM Foods and Beverages

According to [3], Food and beverages sector is a human effort to manage land and agroecosystems with the help of technology, capital, labor, work, and management to achieve food sovereignty and security. The development of food SMEs has many problems including the provision of raw materials, production process and technology, finance, and marketing.

2.3 Brief Concept of Halal

According to [8], Halal is an Arabic word which means lawful, permitted, or acceptable. This concept can be proposed to things like food, manners, actions, physical things allowed by Allah for humanity based on the beliefs of Islam. On the other hand, haram means unlawful, prohibited, or unacceptable. Therefore, halal certificate was created according to Islamic Law with the purpose to overcome the concern of the status of a product for Muslim customers. This also places an important symbol for increasing customer loyalty, improving organization's reputation, and the profit margin.

2.4 Brief Concept of BPJPH and SJPH

According to [1], Halal Product Guarantee Agency or *Badan Penyelenggaraan Jaminan Produk Halal in Indonesian* (BPJPH) is an institution that is managed under The Ministry of Religion. BPJPH functions cover all things related to Halal such as Halal Registration, Halal Certification, Halal Verification, and monitoring the halal status of a product. BPJPH works alongside other organizations such as MUI for Fatwa Halal and LPH.

Halal Product Assurance System or *Sistem Jaminan Produk Halal* in Indonesian (SJPH) is a halal assurance system that is required for Halal certification. It creates and maintains materials, production process, product, resources, and procedure to preserve the integrity of the halal status of a product. There are 5 main criteria that are managed by SJPH. Commitment and Responsibility, Materials, Halal Product Process, Product, and Monitoring and Evaluation.

2.5 Undang Undang No. 33 Tahun 2014

In Law No. 33/2014 [7] it is explained that in Verse 3, there are several institutions that are responsible for Halal Product Guarantee or *Jaminan Produk Halal* (JPH) in Indonesian. First, BPJPH is an Institution that was created by the Indonesian Government to manage JPH. Second, Indonesian Religious Leader or *Majelis Ulama Indonesia* in Indonesian (MUI) serves a place for Muslim clerics to do the fatwa court to discuss about the halal status of a product. Third, Halal Inspection Agency or *Lembaga Pemeriksa Halal* in Indonesian (LPH) is responsible to inspect and conduct a testing towards the halal status of a product.

3 RESEARCH METHODS

3.1 Research Framework

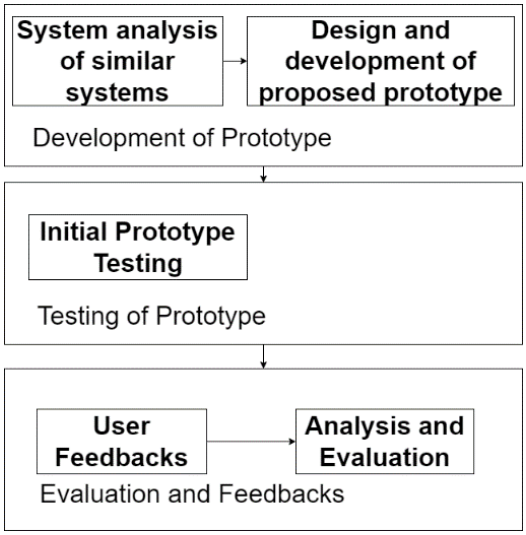

Figure 3: Research Framework of PasporUMKM

3.2 System Analysis and Design

The initial step for the system will be designing the overview diagram using Unified Modelling Language (UML) in which then will be followed by the mockup design of the system by using Figma. The core of the system would be emphasized on the digital platform and cloud service.

3.3 System Analysis and Design

The prototype will be created in a web application system with a functional creation, update, read, and delete SJPH document and its modules. The development will use Webstorm as the main IDE of the web development developed by JetBrains, DigitalOcean as the main provide for the Cloud Server and Storage, and Rumahweb as the domain management system.

3.4 User Acceptance Test and Analysis

User acceptance test will be conducted by testing the current platform on UMKM role with selected respondents and collection of data from the respondents will be done through questionnaire.

4 ANALYSIS RESULTS AND DISCUSSIONS

4.1 Overview Diagram

In the overview diagram from 4, the SJPH segments are being grouped as several modules. Then, there would be a decision making from the UMKM to whether want to be audited and the SJPH will be audited by the auditor. After the auditing process, if the user wants to use the validation service system, then it will use the validation and checking system. The data would then be saved and would be converted into a template of pdf in which the UMKM can use by using the React-PDF Conversion System.

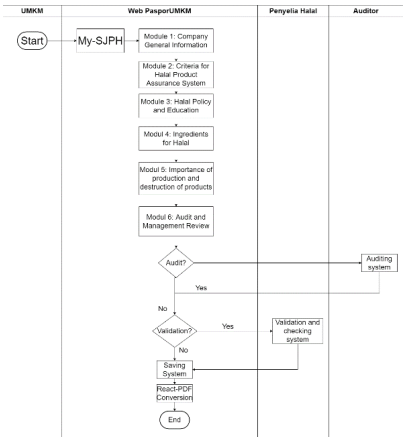

Figure 4: Overview Diagram of PasporUMKM

4.1 Use Case Diagram of PasporUMKM

Figure 5: Use Case Diagram of PasporUMKM

4.2 Architecture Diagram

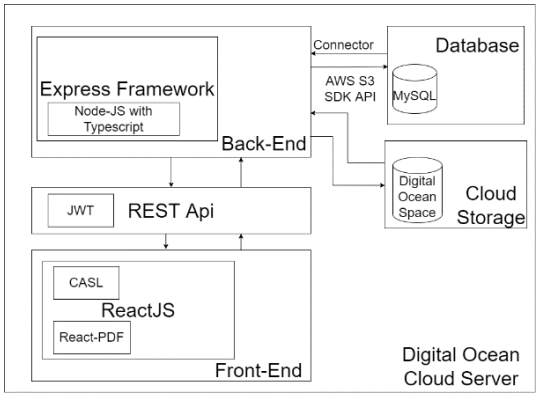

Figure 6: Architecture of PasporUMKM

4.3 Business Process Overview PasporUMKM

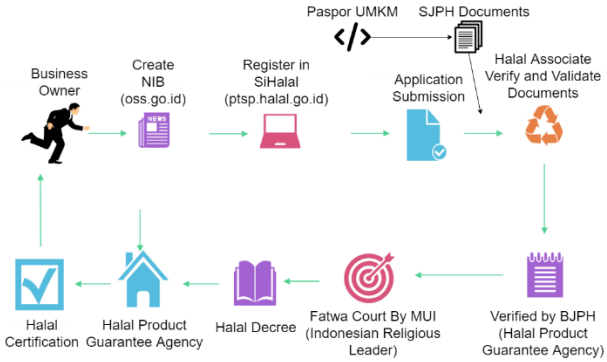

Figure 7: Business Process Overview of PasporUMKM

4.4 PasporUMKM User Acceptance Test

PasporUMKM User Acceptance Test was conducted using questionnaire through Google Form to four selected respondents. The occupation of each respondent comprised of food technology expert, LPH supervisor, and business owner. The average age of the respondents is 30 years old.

There are several main points as features that are created for the platform:

1. Registration Page
2. Login Page
3. Logout Page
4. My-Halal Product Assurance System Page
5. SJPH as preparation for halal assurance system
   a. Company General Information Page
   b. Criteria for Halal Product Assurance System Page
   c. Halal Policy and Education Page
   d. Materials for Halal Purposes Page
   e. Importance of Product Production and Distribution Page
   f. Management Audit and Review Page

The questionnaire had emerged with the average result of 4.10 out of 5.

4.5 PasporUMKM User Acceptance Test Analysis

1. Register

In the registration page, the system functionality works with a stunning performance achieving the score of 4.75 in average. The ease of use for every menu and buttons and the attractiveness of the page design with the score of 4.5. Lastly, the system also performs well for providing information related to registration, easy to understand and the page functioned as what the user expected with a score of 4.25.

2. Login

In the login page, all the system functionality, ease of use, attractiveness, and providing information attained a stellar performance and clear details with the score of 4.75 in average. Moreover, the design of this page is easy to understand, and the page functioned as what the user expected achieving the score for both of 4.5.

3. Home

In the Home page, both system functionality and interface work with a great performance and well attractive achieving the score of 4.5 in average. In addition, the interface in this page is all easy to use, understandable, has provided enough information, and has functioned as what the user expected with the score of 4.25.

4. My-Halal Product Assurance System Page

In My-Halal Product Assurance System Page page, each of the system functionality and interface works with a good performance and attractive as well as understandable and has enough information with the achieving score of 4.25. Additionally, every menu and buttons are easy to use with the score of 4.5. The page functionality also performs well regarding with the context of SJPH and shows the result as expected with a score of 4.

5. Company General Information Page

System functionality in Company General Information Page works with a great performance achieving the score of 4.5 in average. Moreover, the interface in this page is all easy to use, understandable, has provided enough information, well created according to the SJPH context, and has functioned as what the user expected with the score of 4.25.

6. Criteria for Halal Product Assurance System Page

In Criteria for Halal Product Assurance System Page, each of the system functionality and interface works with a fair performance, easy to use, and attractive as well as understandable and has enough information with the achieving score of 3.75. Then, the page functionality also performs fairly regarding with the context of SJPH and shows the result as expected with a score of 3.5.

7. Halal Policy and Education Page

In Halal Policy and Education Page, each of the system functionality and interface works with a good performance and attractive reaching the score of 4. Next, every menu and buttons are satisfactory to use alongside with the functionality with the context of SJPH with the score of 3.5. Last, the page has comprehensible interface with the information was decent for the users to understand, and shows the result as expected with a score of 3.75.

8. Materials for Halal Purposes Page

In Materials for Halal Purposes Page, each of the system functionality and interface works with a good performance, easy to use, and attractive as well as intelligible and has enough information with the achieving score of 4. The page functionality also performs adequately regarding with the context of SJPH and shows the result as expected with a score of 3.75.

9. Importance of Product Production and Distribution Page

In Importance of Product Production and Distribution Page, each of the system functionality and interface works with a good performance, easy to use, and attractive with the attaining score of 4. Furthermore, the page functionality performs comfortably regarding with the context of SJPH with a score of 4. Then, the information from the page and interface are clear, understandable to use, and as stated by the context of SJPH with the score of 3.75.

10. Management Audit and Review Page

First, the system functionality and interface work with a good performance and easy to be used with the score of 4. Second, the respondents agreed that the interface in this page is appealing with the score of 4.25. the information and interface are concise and comprehensible with an addition of decent functionality process that is according to the SJPH alongside of the result that is expected by the user with the score of 3.75.

4.2. PasporUMKM User Acceptance Test Evaluation

Within the questionnaire, there is a field on each of the module. This field functioned to gather user feedbacks according to the values that are being questioned. In result, there are several feedbacks tangible with each of the module as of:

1. Registration Page

The color preferably changed as more contrast with the theme to create an additional pleasant interface.

2. Home Page

Respondents requested for additional features in particular functions for preparing documents before writing SJPH and halal registration. Additionally, button for the dark mode seems not clear for the user.

3. My-Halal Product Assurance System Page

Respondent responded that the document for the whole SJPH does not really need to be created for multiple times and one time only.

4. Company General Information Page

If the user has not yet saved several mandatory inputs, then the users are not able to continue along the journey.

5. Criteria for Halal Product Assurance System Page

The inputs are more desirable with filled example in the placeholder.

6. Halal Policy and Education Page

First evaluation discusses about the creation of list of attendees table input with more simplistic approach and additional feature like import data from list of attendees excel file to reduce confusion. Next, the recommendation of the approach that the user only edit sentence that can be edited from the template in halal policy.

7. Materials for Halal Purposes Page

Firstly, a notice was given that this is going to be the most engaged and dynamic page since most of the documents will serve as a recurring document for daily activities. Moreover, there is a typo within the sub-module of the number four button. Next, language consistency must be preserved. Furthermore, there is a confusion of whether the number one sub-module until the number four are always going to manage around agreement document. Lastly, a recommendation for only one cancel button is necessary for the pop-up window.

8. Importance of Product Production and Distribution Page

In the sub-module of Production Flow Chart, the user should be allowed to create the document with a text narration alongside with the rules for the layout of halal certification.

9. Management Audit and Review Page

Additional example is needed to lessen any confusion.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the research conducted, there are several points that are concluded.

First, the research performed had resulted in the creation of the first prototype of PasporUMKM online platform with a functional documents creation for the UMK based on the halal assurance system documents.

Second, based on the result of the test conducted for the first prototype, the system can be able to provide information for the users with the role of UMKM for the requirements to create the halal assurance system document.

5.2 Recommendations and Future Work

The prototype itself is not yet fully functional due to the time limitation of the research. Additionally, there are also functions that need to be added and adjusted based on the evaluation due to feedbacks from the users that provided a helpful insight to improve the prototype to the market.

REFERENCES

[1] Aini. 2021. SERTIFIKASI HALAL PRODUK PANGAN DI BADAN PENYELENGGARA JAMINAN PRODUK HALAL (BPJPH).

[2] Lukmanul Hakim. 2011. SURAT KEPUTUSAN LEMBAGA PENGKAJIAN PANGAN, OBAT-OBATAN DAN KOSMETIKA MAJELIS ULAMA INDONESIA Tentang REVISI KETENTUAN KELOMPOK PRODUK BERSERTIFIKAT HALAL MUI. Majelis Ulama Indonesia, Jakarta.

[3] Musa Hubeis, Budi Purwanto, Farida Ratna Dewi, Hardiana Widyastuti, and Mita Febtyanisa. 2015. Developing Strategies of Competitive-Food Small Medium Enterprises in Indonesia. *Prosiding Seminar Hasil-Hasil PPM* I, 1 (2015), 126–143.

[4] Muhammad Aqil Irham. 2021. KEPUTUSAN KEPALA BADAN PENYELENGGARA JAMINAN PRODUK HALAL NOMOR 141 TAHUN 2021 TENTANG PENETAPAN TARIF LAYANAN BADAN LAYANAN UMUM BADAN PENYELENGGARA JAMINAN PRODUK HALAL.

[5] Muhammad Aqil Irham. 2022. KEPUTUSAN KEPALA BADAN PENYELENGGARA JAMINAN PRODUK HALAL NOMOR 33 TAHUN 2022 TENTANG PETUNJUK TEKNIS PENDAMPIGN PROSES PRODUK HALAL DALAM PENENTUAN KEWAJIBAN BERSERTIFIKAT HALAL BAGI PELAKU USAHA MIKRO DAN KECIL YANG DIDASARKAN ATAS PERNYATAAN PELAKU USAHA. (2022).

[6] Pemerintah Indonesia. 2021. Peraturan Pemerintah Republik Indonesia Nomor 07 Tahun 2021 tentang Kemudahan, Pelindungan, dan Pemberdayaan Koperasi dan Usaha Mikro, Kecil, dan Menengah. 086507 (2021), 1–121.

[7] Republik Indonesia. 2014. Undang – Undang Republik Indonesia No. 33 Tahun 2014 Tentang Jaminan Produk Halal. *Undang – Undang Republik Indonesia* (2014), 1–40.

[8] Normia Akmad Salindal. 2019. C

A Study on the Development of an Online Book Publishing Funding Platform

This paper analyzes further into the creation of an online platform to fund book publishing processes.

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ABSTRACT

The process of publishing printed books require initial capital investment from publishers, which limits the number of new book titles published in Indonesia. Additionally, publishers lack the funds to publish new titles due to the decline in book sales caused by the Covid-19 pandemic. This research aims to solve funding issues towards book publishing, which is allocated towards printing physical copies. A business analysis was conducted to analyze the feasibility of the business model of the proposed solution and the unique value proposition that is offered to the market. A prototype is also developed as a proof of concept to demonstrate how the proposed solution would take form. The prototype was demonstrated to interviewees to gain feedback for evaluation, which concludes that the proposed solution has promising value to be used by Indonesian publishers.

CCS CONCEPTS

• **Software and its engineering**; • **Software creation and management**; • **Software verification and validation**; • **Software prototyping**;

KEYWORDS

Crowdfunding, Online marketplace, Peer-to-peer lending, Server-side rendering

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1 INTRODUCTION

Book publishing entails a series of steps in order to turn raw scripts written by authors into books available and ready to purchase in stores. Manuscripts are first reviewed by publishers to analyze whether the story would garner the interests of its targeted audience amongst book readers. If the script were to be approved for publishing, they would then proceed to begin working on processing both its content and its context [1]. Editing script content ensures the appeal of the story or information to be clearer and more engaging, while context processing involves marketing and sales management: from layout and cover editing, ISBN registrations, until the books are distributed to stores to be sold.

According to book publishers in private conversations prior to this research, they have claimed to receive numerous scripts from authors to be published into books, yet are selective in choosing which titles should be published. This is due to the fact that book publishers are operating their business with a significant risk. Since book publishing and printing are normally funded by publishers, it is in their best interest to carefully consider which titles to publish in order to be profitable.

This suggestion is relevant to existing data from the National Library of Indonesia (Perpusnas RI), which holds the data of book titles and publications associated with an International Standard Book Number (ISBN) published in Indonesia. Even though the number of book titles has been increasing annually within the 2016-2020 period, its growth rate has been constant, ranging from 20,000 to 25,000 increase annually.

This data has not accounted for the decline of book publishing due to the Covid-19 pandemic, which has been a global issue that has impacted most industries in Indonesia since 2020. Statistics according to the Indonesian Publishers Association (IKAPI) has shown that 82.7% of Indonesian publishers experience moderate to major decline in business productivity, and 58.2% of publishers saw a higher than 50% decline in sales than normal since the pandemic [2]. Similar statistics from the Indonesian Ministry of Tourism and Creative Economy (Kemenparekraf) further claimed that 96% of Indonesian publishers have been affected by the pandemic, about 28% of which did not publish any new book titles [3].

The points mentioned above justifies the need to conduct research towards new means of funding to publish new book titles in Indonesia.

2 RELATED WORKS

A study is found regarding the development of an online platform to promote investments of a business process. Sistem Ternak Cerdas is a platform that connects farmers with investors in the animal husbandry industry [4]. Farmers who have difficulties to gain financial aid for their farms can request funding to improve their farms, where at the time, were still dependent on imported cows for milk. However, the scope of this particular study is only to the extent of system analysis (usability testing).

Another example of an already-established investment platform that invests in goods and services is a case study of iGrow.asia. iGrow is a start-up company that would assist the funding and investment of production mechanisms in organic farming [5]. It was founded in 2013 and connected investors to farmers and field/land owners in hopes to participate in the farming industry. The platform also serves to reduce the dependency of farmers towards certain parties for their funding needs. According to its website [6], it has funneled Rp. 462.8 billion in investments with a success rate (TKB90) of 97.53%.

On the other hand, Tokopedia is an online marketplace established in 2009 [7]. Founded by William Tanuwijaya and Leontinus Alpha, it is one of the most used e-commerce platforms by Indonesian consumers. Tokopedia offers various features for sellers using their platform, which can be online retail stores of big businesses or individuals. These features include a pre-order system, usually used for goods being imported from overseas. The platform also contains book catalog for curated books and new releases, making it an option worth considering for publishers.

3 BUSINESS ANALYSIS

As initially stated, the book publishing process requires a lot of capital to fund. The funds for publishing are mostly allocated towards cost of printing physical copies of books. The source of capital is usually provided by publishers; therefore, it is crucial for them to, at the very least, gain their capital back from the published books by considering which titles would be profitable to publish. Publishers have limited capital to fund scripts to be published, and the issue is made worse due to the Covid-19 pandemic, which caused a significant decline in book sales [2]. The stakeholders affected by this problem are: publishers, authors, printing services, distributors, retailers, and readers.

There are several well-established competitors currently in the market that offers solutions to ease the problem. Wattpad is an online storytelling platform founded by Allen Lau and Ivan Yuen in Toronto, Canada. Since its launch in December 2006, the platform has grown to have more than 90 million users–including authors–and 23 billion minutes of collective usage time a month [8]. The function of Wattpad is to provide writers (or authors) a platform where they can publish their original works without the need to worry of traditional book publishing methods, such as printing and distribution. Readers using the platform are then exposed with original stories of varying genres to read from their desktop or on the go with their mobile phones. As a result, writers would be able to engage more with their readers to form a community. Stories created in Wattpad could either be published as free-to-read or as a Paid Story. Paid Stories only allow free readers to read the first several parts of a story, whereas the rest of the story could be unlocked by spending 'Coins', which could be earned by watching advertisements (up to 3 coins per day), or purchased through the iOS App Store or the Google Play Store, depending on the mobile platform used by the users.

Unbound is a book publishing company founded in June 2010 by John Mitchinson, Dan Kieran, and Justin Pollard. It uses a crowdfunding system to gather necessary funds from interested readers to support the publishing of a new book title. According to their statistics, Unbound has a community of over 300,000 readers all over the world that has contributed £11 million to fund a total of 620 book titles to be published [9]. In a crowdfunding system, authors are encouraged to create a proposal for a book concept. This is done to pitch their ideas and attract readers to be inclined to purchase the book. Authors then set a certain funding target which they should achieve within a defined window of time. To attain this goal, they would open book pre-orders to allow readers to purchase physical copies of the book, even when the book is neither published nor printed yet.

Publishizer is an online book crowdfunding platform founded by Lee Constantine and Tobias Lorenz in May 2015. It shares several similarities with Unbound, in which it uses a crowdfunding system to fund book publishing. In Publishizer, authors pitch a book idea by writing a proposal to the Publishizer team to launch the crowdfunding campaign. Authors then generate attention towards the campaign, and successfully creating a trend within the platform would promote the project even further by having the platform feature the campaign in a weekly digest [10]. Publishizer differs with other platforms, in which authors would receive offers from multiple publishers, ranging from small publishing imprints to large publishing houses, depending on the target goals achieved. Authors get to evaluate and choose the best offer and work with a publisher, or decide to self-publish if they desire.

Tokopedia can also be considered as one of the existing established competitors which are available in Indonesia. Using its pre-order system, book sellers are able to accurately estimate the market demand for each title being sold. Tokopedia also has a large user base, making it easier for anyone to purchase books without having to register new accounts for a new platform. There are a few notable drawbacks to the pre-order system implemented by Tokopedia, which is that the money paid by buyers are being withheld by the platform. This means that publishers have no access to this funds that could be utilized to produce books. Sellers are also obliged to fulfill pre-order requests at a maximum of 90 days after a purchase has been made.

After taking existing competitors into consideration, the proposed solution could implement one or several methods to solve the identified problems. The conventional methods of fundings used by competitors include a pre-order system and a crowdfunding campaign. On the other hand, funding through investment or peer-to-peer (P2P) lending has not yet been commonly implemented in this industry.

As a novel idea, P2P lending is the preferred method of funding for the proposed solution. The fact that none of existing solutions in the market uses P2P lending is a unique value proposition that would benefit the proposed solution as a business idea. However, the difficulty in developing an online lending platform lies in the

<table>
<tr>
<td rowspan="2">Key Partners
• Credible authors/ influencers
• IT server management/ cloud service provider</td>
<td>Key Activities
• Feature development
• Content curation
• Marketing</td>
<td rowspan="2">Value Proposition
• Guarantees the management of funds generated from pre-order sales, which can be directly allocated towards printing and distribution.
• A catalog of projects that printing services can offer their services to.</td>
<td>Customer Relationships
• Newsletters
• Feedback
• Marketing campaigns</td>
<td rowspan="2">Customer Segments
• Publishers who have limited capital to fund the publishing of new book titles.
• Printing services that have difficulties in getting printing requests from publishers.</td>
</tr>
<tr>
<td>Key Resources
• IT-related resources
• Exclusive catalog of content</td>
<td>Channels
• Web site
• Email
• Social media</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• IT infrastructure costs
• Marketing and advertising</td>
<td colspan="2">Revenue Streams
• Fixed rate of charge/flat fee to publishers
• Fixed rate of charge/flat fee to printing services</td>
</tr>
</table>

Figure 1: Business Model Canvas

compliance with existing regulations, particularly from Otoritas Jasa Keuangan (OJK), which is the authority related to financial services in Indonesia.

According to OJK Regulation (POJK) No. 77/POJK.01/2016, the management of online P2P lending platforms must be under the jurisdiction of a legal entity registered in Indonesia, and the registration of the platform to be certified by OJK requires an extensive application process. The platform should also comply with standards set by the regulation, which is outside the scope of this research.

Therefore, this research will proceed using a pre-order system as the method of funding in the creation of the prototype. An alternative method of development using P2P lending would be suggested as a recommendation.

A business model canvas (BMC) is a tool first introduced by Alexander Osterwalder and Yves Pigneur through their book published in 2010, Business Model Generation. Through a BMC, potential businesses can visualize the value proposition that they bring to the market and strategies on how to make use of key resources, partners, and activities required to deliver said value proposition. The BMC also helps to understand the relationships and channels that would deliver the value proposition to each customer segment, as well as the cost structure and revenue streams of the business.

Figure 1 shows the BMC of the proposed solution. The focus of the value proposition in this case study would be a pre-order system that uses the funds collected from purchases to directly be used towards the publishing (mainly printing) of books, and also a catalog of printing services that the publishers could choose to get the best offer for their needs. This value proposition is unique compared to other competitors such as Tokopedia, which guarantees product delivery by withholding the pre-order revenue until the product has been delivered to the customer.

The key resources required for the business are exclusive catalog of books only obtainable through the platform and IT-related resources to operate and maintain the platform. These resources can be obtained by working with credible authors/publishers/influencers and IT cloud service providers respectively as key partners. The key activities of the business involve platform development and maintenance, content curation, and marketing. The cost structure of the business is mainly to fund the IT infrastructure for the platform, and to cover marketing costs.

The value proposition is targeted to publishers who aim to publish more book titles without concern of initial capital, and printing services who aim to acquire more printing requests from publishers. The business builds relationships with its customers through newsletters, feedback collection, and marketing campaigns through channels such as web sites, emails, and social media platforms. The revenue stream of the business may come from a fixed rate of charge or a flat fee that could be charged from the publisher and/or the printing service provider.

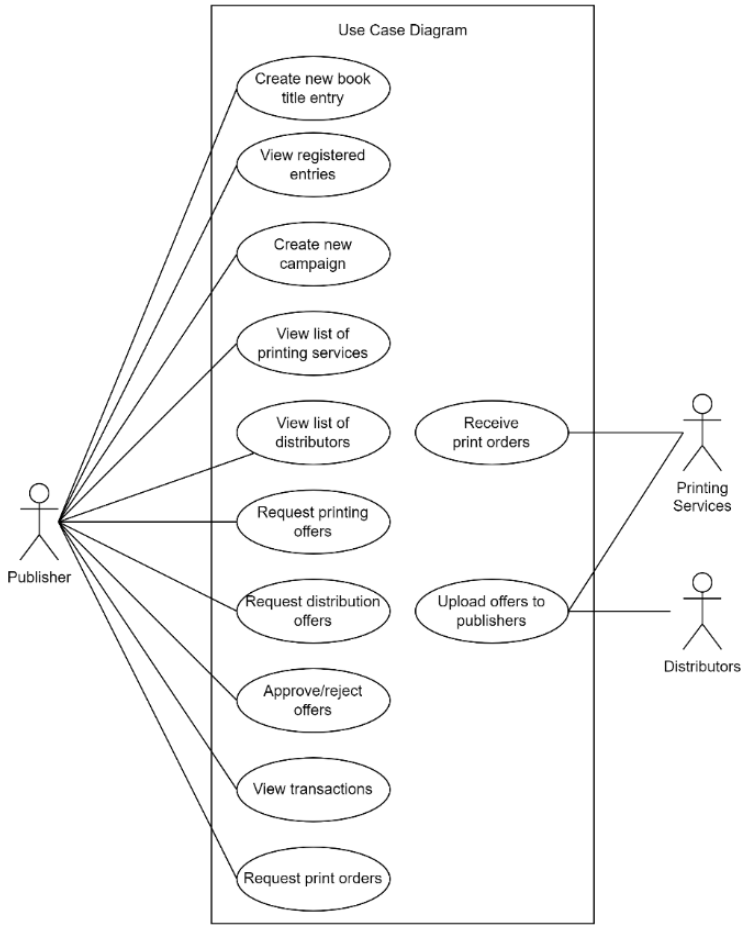

Figure 2: Use Case Diagram

4 PROTOTYPING & TESTING

The business analysis process summarizes the value proposition that should be adopted by the proposed solution. The features that should be included are the facilitation of a pre-order system and a catalog of printing services.

In order to create a pre-order campaign, publishers have to create a new book entry that contains the metadata of the book, such as subtitle, synopsis, etc. There will be a distinction between books and campaigns, as one book title may have another round of pre-order campaign in the future.

The funds collected by the platform through pre-orders should be managed by the platform to be delivered directly to the printing service of choice upon requests of new printing orders. The funds are managed by the platform to prevent mismanagement of capital by the publishers, as they may withdraw the funds without fulfilling the purchase orders.

A catalog of available printing services will be accessible by the publishers upon creating a new pre-order campaign. Publishers will be able to request offers from multiple printing services and evaluate which offer would be the most suitable for their needs.

The system should also consider the user experience (UX) aspect, which describes the interaction between the user and the system. This involves the ease of use and the efficiency of the system workflow.

A use-case diagram illustrates the relevant actors in a system and the functions that they will be interacting through operating the system. A use-case diagram of the system is described in Figure 2.

An activity diagram illustrates the processes that occurs within a system during user operation. The diagram shown in Figure 3 explains the initial steps of the creation of a new pre-order campaign by publishers. The development of the prototype will be based on this diagram.

The prototype is developed as a web-based application platform. The React framework used in the development utilizes the single-page application concept, in which all the features of the application are rendered from the server as a single HTML file. This means that all the required assets are loaded upon accessing the web page, only requiring the client to interact with the server once.

An interview is conducted to obtain feedback to be used as evaluation of the prototype. After demonstrating the prototype,

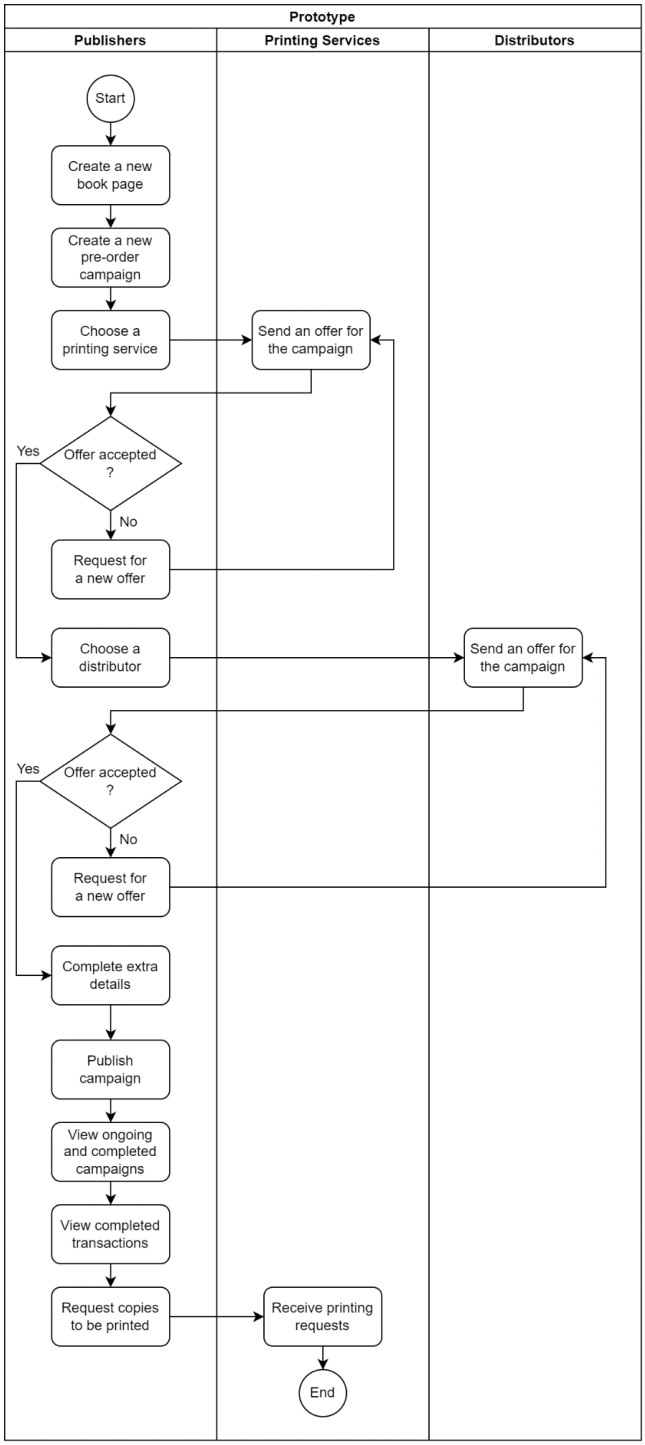

Figure 3: Activity Diagram

the interviewee was asked several questions which are attached in Appendix A, including answers in Bahasa Indonesia.

The interviewee, Denny Indra, is the operational director at PT. Sarana Kata Grafika, a company that offers printing services to book publishers. He has experiences in the printing industry for almost 10 years, with prior experiences working for several book publishers.

The key points of the interview regarding the business model are:

- The business idea behind this platform (directly allocated pre-order funding) has been circulating in the past, but has not been further realized and developed,
- The platform as a proposed solution will certainly solve the problems that a publisher may have, including the ease of negotiations between a publisher and a printing service, assistance to fund book printing, and publicize books as a marketplace.
- Printing services profit from book printing by a small margin, therefore the platform should evaluate carefully how fees would be charged to printing services.
- The platform has a potential to evolve into a direct competitor to book publishers that they work with, which may cause hesitance for publishers to use the platform in the future.

The feedbacks after testing the prototype are:

- There should be alterations in the workflow of the prototype; publishers should define the desired specification of the physical copy, which includes paper thickness, cover finishing, book binding, and more.

In addition, instead of a catalog of printing services accessible to publishers, it is more suitable to create a catalog of projects accessible to printing services. Printing services should be able to view the desired specifications of the books to be printed, and offers their price for the publishers to consider. This process would be similar to a bidding process, where printing services bid the best offer to fulfill a printing order.

5 CONCLUSION

The process of publishing a book, mainly printed books, requires initial capital to fund. This risk of investing capital is normally borne by book publishers, which limits the number of book titles that can be published annually.

This research seeks to consider other funding methods that would assist publishers in generating capital at a lower risk, which can be used to fund book publishing and printing. These funding methods include a pre-order system, crowdfunding, and investment through peer-to-peer (P2P) lending. This would be a unique value proposition that can serve as the foundation of a novel business idea.

This research has answered that the proposed solution would in fact be a very beneficial platform for publishers to join, not only due to the decreased risk of capital loss, but also due to the ease of negotiations with printing service providers to get the best possible offer.

The potential for the proposed solution to be developed into a start-up business is considerable, but a lot of work still has to be done to achieve that goal.

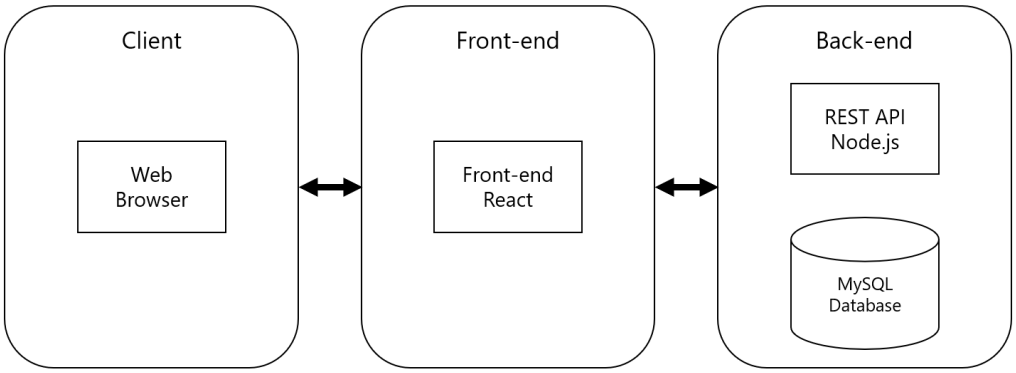

Figure 4: Architecture Diagram

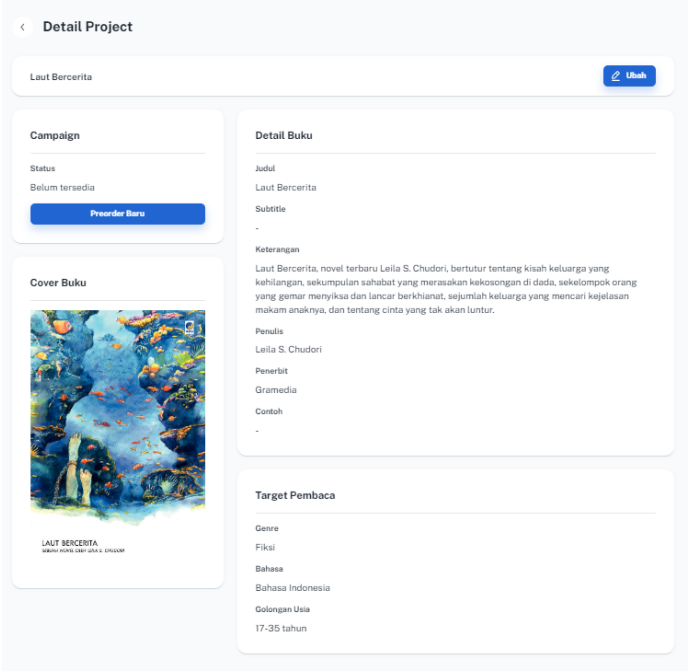

Figure 5: Prototype Sample – Details Page

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REFERENCES

[1] Zoe Sadokierski. 2014. How publishing works: a book designer's perspective. *The Conversation*. Retrieved December 12, 2021 from https://theconversation.com/how-publishing-works-a-book-designers-perspective-32211

[2] IKAPI. 2020. Resume Survei Dampak Covid-19 Terhadap Industri Penerbitan Buku Di Indonesia. *Ikatan Penerbit Indonesia*. Retrieved June 9, 2022 from https://www.ikapi.org/riset/

[3] Kemenparekraf. 2022. Hari Buku Nasional, Pemulihan Industri Penerbitan Harus Mulai dari Sekarang. Retrieved June 13, 2022 from https://www.kemenparekraf.go.id/destinasi-super-prioritas/hari-buku-nasional-pemulihan-industri-penerbitan-harus-mulai-dari-sekarang

[4] Muhamad Thanthawi Jauhari. 2020. Platform Investasi Peternakan "Analisis dan Perancangan Prototipe Sistem Ternak Cerdas Berbasis WEB." *Petir* 14, 1 (October 2020), 61–70. DOI:https://doi.org/10.33322/petir.v14i1.1002

[5] T. Widiastuti, R. Sukmana, I. Mawardi, Wahyuningsih, and I.W. Indrawan. 2018. The role of financial technology for the agricultural sector in Indonesia: Case study of I-Grow FinTech company. In *Increasing Management Relevance and Competitiveness*. CRC Press, 509–514. DOI:https://doi.org/10.1201/9781351241892-93

[6] iGrow. 2021. Pendanaan pertanian berdampak sosial, aman, dan profitable. *iGrow Resources Indonesia*. Retrieved January 14, 2022 from https://igrow.asia/about

[7] Anggi Sasmita, Yuli Marta Ambarita, and Annie Mustika Putri. 2021. Strategi Pemasaran Tokopedia dalam Persaingan Antar E-Commerce dengan Analisis SWOT. *Jurnal Pendidikan Tambusai* 5, 2 (2021), 3397–3404.

[8] Wattpad. 2021. Naver Completes Wattpad Acquisition. Retrieved April 13, 2022 from https://company.wattpad.com/blog/naver-completes-wattpad-acquisition

[9] Unbound. 2022. About us: Unbound. Retrieved April 13, 2022 from https://unbound.com/about

[10] Publishizer. 2022. Frequently asked questions - Publishizer. Retrieved April 13, 2022 from https://publishizer.com/about/faq/

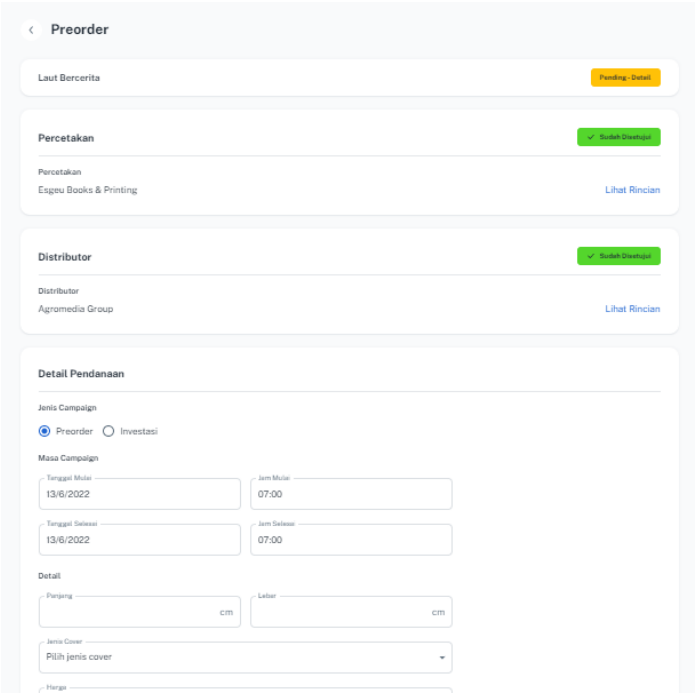

Figure 6: Sample Pre-order Page

No.	Features	Very Poor	Poor	Sufficient	Good	Very Good
1.	Pre-order Capabilities					3
2.	Selection of Printing Services			1	2	
3.	Negotiation System			1	1	1
4.	Funding Management				1	2
5.	Status Transparency					3

Figure 7: User Acceptance Test

Analysis of the Application of Communication Information Technology in Micro, Small and Medium Enterprises

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ABSTRACT

Technology is something that cannot be separated from human life from small children to adults, including in the field of micro, small and medium enterprises of Indonesian society, this causes the need for surveys and analysis as well as examples of the application of communication technology in micro, small and medium business flows, by researching in the community about the application of technology in micro and small businesses using field survey methods and the data results will be displayed quantitatively, it is hoped that they will find needs that are in accordance with the interests and needs of micro and small business actors so that they can be more efficient in using information technology and communication.

CCS CONCEPTS

• **Electronic commerce** → E-commerce infrastructure; Human-centered computing; Human computer interaction (HCI); HCI theory, concepts and models.

KEYWORDS

Micro, small and medium enterprises, communication information technology, Human Computer Interaction, technology infrastructure

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1 INTRODUCTION

Technology is a very broad term and is used to refer to it. Several fields of science and research. The term "technology" The Greek word "engineering" means "craft" and "logia" means "the study of something". One example of technology is information technology. As a technical field that has long been established in various fields of science and technology, it is necessary to have research on the technology needs in Indonesian society, especially in the micro, small and medium business sector.

As in the world of micro, small and medium businesses which are closely related to buying and selling transactions, information technology can also be used for commercial purposes known as E-commerce. E-commerce can be used to buy, sell and market goods and services through electronic systems such as the Internet, TV and computer networks. E-commerce can include transfers such as electronic money, electronic data exchange, automated warehouse management systems, automated data collection systems. and E-business.

The application of information technology is also widely carried out by entrepreneurs. because of the need for time and cost efficiency, all divisions feel the need to implement information technology in the work environment.

So with increasing public awareness of technology, it is necessary to have a field survey that examines the needs and needs of the community, especially micro, small and medium enterprises on the need for technology.

Definition Of Information Technology According To Experts

[1] Digital is an electronic technology that can store, generate, and process various data contained in two states, positive and negative. Positive conditions are represented by the number 1 and negative conditions are represented by the number 0

[2] the data generally follow the customs commonly used or agreed upon by many people. For example, in some places this is an old practice. Adat has become an old tradition, so it is considered normal or already well known.

[3] Websites can provide more efficient and always new information. This website is more easily accessible by people from various regions through the internet. For example, this website can be used for media marketing, information, education, communication, and advertising. This website is also a very suitable medium to present the various possibilities and benefits of the product you want to sell to the wider community.

[4] As the amount of data increases, the database process slows down and the system performance slows down, so you need to update the system containing your database again. Database related updates are done by migrating the database management system (DBMS) from MongoDB to MySQL. The database migration procedure begins with collecting data, sorting (extracting) data, modifying (changing) data, and loading data into the target DBMS. The migration and database mapping process can only be done using programming languages such as JavaScript and Python.

[5] When processing a very large amount of data, the stored data varies greatly and the change in data is called big data.

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[6] Database is a system for managing data on computer systems. There are several database systems that have their own rules and ways of working. Data is organized at different levels. On computers, data is categorized into hierarchies. The higher level consists of one or more lower level data

[7]That is, a collection of raw facts or information such as numbers, words, pictures/pictures, symbols, etc., which are obtained through the process of searching or observing from certain sources.

[8] Server can only be a computer for some application services. Or, if your network is more complex and complex, you can set up a server to provide only one or a few services and delegate other services to other servers. Multiple servers work together to provide services and information to multiple clients.

[9] A web server is a machine that can handle client requests. After installing the software and connecting to the Internet, you can turn your computer into a web server. Web servers are usually responsible for receiving and processing HTTP requests from web clients on web pages that contain static content (text, images, and so on). Dynamic content (scripts). .. Therefore, the main task of a web server is to store and process files and to serve web page requests to clients through a communication protocol between the client and server that uses Hypertext Transfer Protocol (HTTP).

Objectives Of Information Technology For Small Medium Micro Business

Solving problems

The existence and development of the world of science and technology is very rapid, this amazing thing certainly brings enormous benefits for progress. Human civilization. Types of work that previously required skills Physically large enough to be relatively mechanically replaceable Automatically and as if finding a new formulation of computer capacity

Successfully repositioning the capabilities of the human brain in various fields of science and technology Human activities. The scientific and technological advances we have made are now truly recognized. And it is felt that it brings a lot of convenience and comfort to people's lives

Creativity

Creativity is basically a general ability to create something Like the ability to come up with new and new ideas Applicable to problem solving or as a feature to identify new relationships between existing elements

Effectiveness

Effectiveness is the heavy use of resources, equipment and infrastructure. Certain things that are consciously predetermined to produce a certain amount of work On time.

Efficiency

Efficiency Use of minimal resources to achieve optimal results

2 RESEARCH METHODS

Research Locations and Research Time

Research sites

The research activity was held in the Nirwana Cilangkap housing complex, East Jakarta

Research time

This research was conducted on 18-19 June 2022

Population and Research Sample

Research Population

The population in this study were all residents of the nirvana cilangkap housing estate, totaling 100 people, which were divided into 50 women and 50 men, as well as 10 micro, small and medium enterprises in nirvana housing.

Research Sample

Qualitative research is subjective, researchers interact directly with residents and micro small and medium business actors with random sampling techniques, interview residents and micro small and medium business actors about the application of communication information technology to the buying and selling process in everyday life.

3 RESULTS AND DISCUSSION

The results of interviews and discussions from various sources contain various graphs and conclusions which will be summarized as follows:

Framework in a research

Technology Utilization Survey Graph

In the graph above, it can be concluded that women use E-commerce more than men

In the graph above, there are 8 sellers in Nirvana housing who have used E-commerce as a place to selling

Conclusion of Technology Utilization Interview

Advantages of technological advances for micro, small and medium enterprises and the community

- The speed of information makes Time no longer a barrier to communication between sellers and buyers
- Megapixel image and video clarity, and audio clarity in ad creation
- The accessibility of micro, small and medium enterprises and the community becomes easier to buy and sell because of easy access
- Dissemination of information, transmission of messages or sharing of promotional closeness, to obtain information from sellers and buyers

Challenges of technological advancement for micro, small and medium enterprises and the community

- Faster, easier, shorter . cause social changes faster than ever that affect the change in the value of the Promotion.
- lack of government support for technology development
- There are no new innovations in this type of manufacturing technology because the tools are expensive for micro, small and medium enterprises
- Lack of teachers in technical preparation in training micro, small and medium enterprises in technology
- Global change is not always positive. Which destroys the image of micro, small and medium enterprises
- Lack of interest in micro, small and medium enterprises entering the world of technology

The function of technology for micro, small and medium enterprises and the community

- Capture, i.e. Detailed activity-to-activity log optimization on micro small and medium enterprises

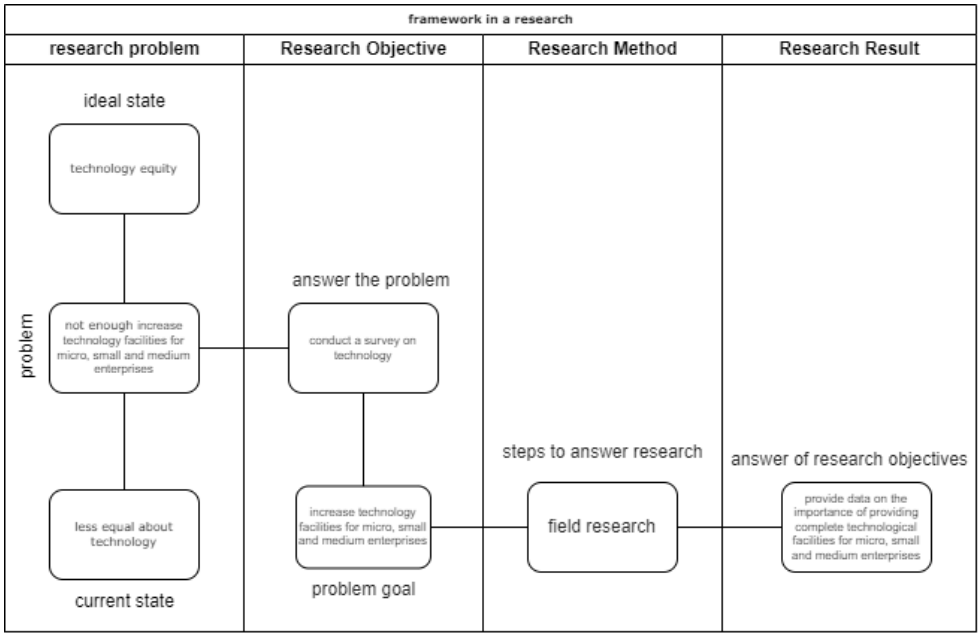

Figure 1: Framework in a research

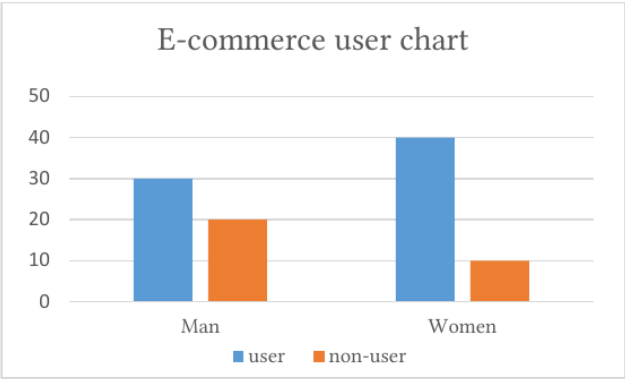

Figure 2: E-commerce user chart

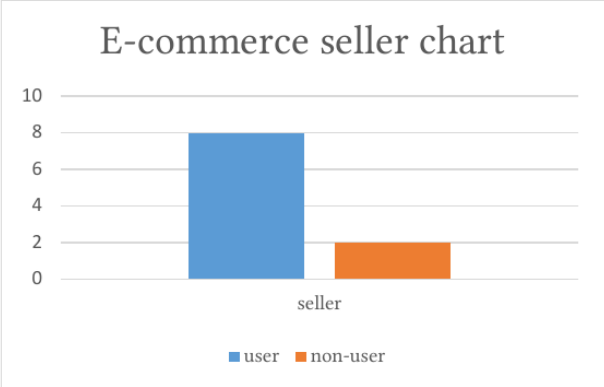

Figure 3: E-commerce seller chart

- Processing, Processing or processing received input data to become information.
- Storage is the activity of recording or storing micro, small and medium business data in Cloud Storage
- Retrieval is an activity of tracing, retrieving information or copying stored data and information. For example, looking for suppliers who have paid off,
- Send (send) and send data and information from one place to another through a computer network. For example, sending sales data from employees to owners

Barriers to the advancement of technology for micro, small and medium enterprises and the community

- Technology costs are still high
- Slow technology acquisition for micro, small and medium enterprises and the community
- Lack of teachers and technology activists in the morning, micro, small and medium businesses and the community
- Social impact in people's lives

Infrastructure needed by micro, small and medium enterprises and the community

- Hardware
- Software
- Network and communication
- Database
- Personal information management

From the results of the survey above, it can be concluded that applications that are suitable for micro, small and medium enterprises are applications that are easy to make and easy to use, so the

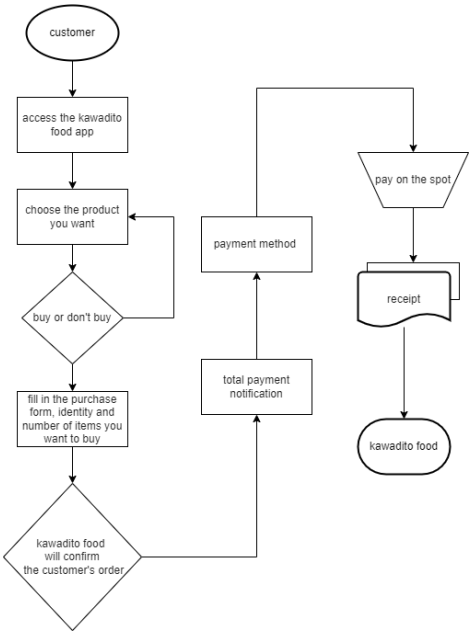

Figure 4: Flow chart

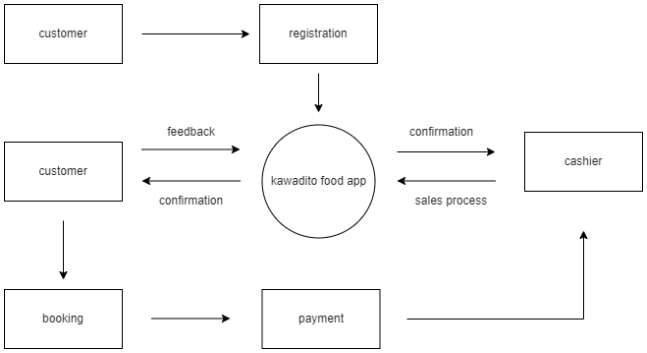

Figure 5: Data flow chart

researcher will give one example of making an application that is easy to use as follows

- **Flow Chart**

The design of the kawadito food application system starts from the flow chart of the purchase of goods by the customer which shows the steps and decisions to carry out a process from a program on the kawadito food application.

- **Kawadito food application data flow**

Diagram Data flow diagram or DFD is a diagram that describes the data flow of a process or information system that is in a Kawadito food store.

- **Use Case Diagram**

Use case diagrams are UML (Unified Modeling Language) diagrams that describe the interaction between the Kawadito Food system and the customer.

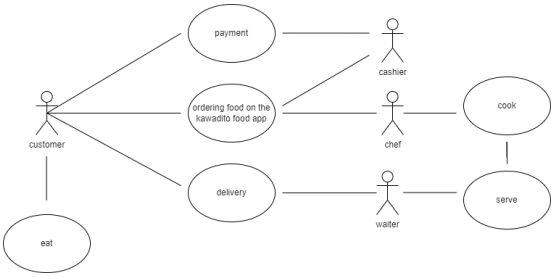

Figure 6: Use Case Diagram

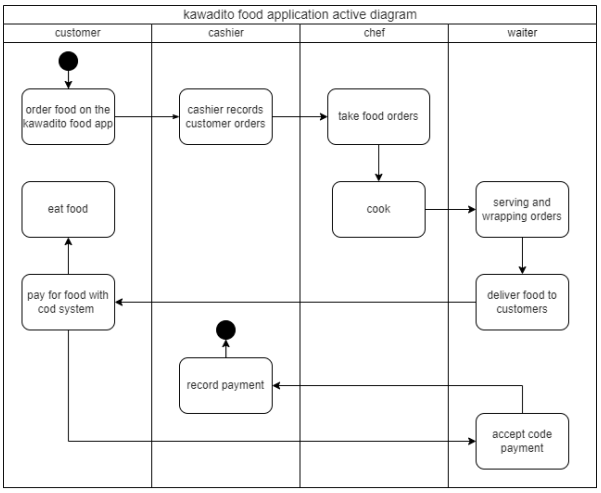

Figure 7: Activity Diagram

- **Activity Diagram**

is a sequence of processes running a kawadito food system which is depicted vertically

- **ER Diagram**

ER diagram is a diagram used for designing a Kawadito food database and shows the relationship between objects or entities and their attributes in detail.

- **Kawadito Food Application Database**

Because ordering kawadito food uses google form, the kawadito food database is integrated with Microsoft Excel as shown

4 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION

In the research above, it can be concluded that there has been an awareness of technology in society in Indonesia but it still needs to be improved due to the lack of technological facilities in Indonesia.

SUGGESTIONhopes and suggestions for the advancement of information technology for Micro, Small and Medium Enterprises is to expand the spread of technology to the wider community in Indonesia, especially for Micro, Small and Medium Enterprises because many still use the old or conventional way in their business

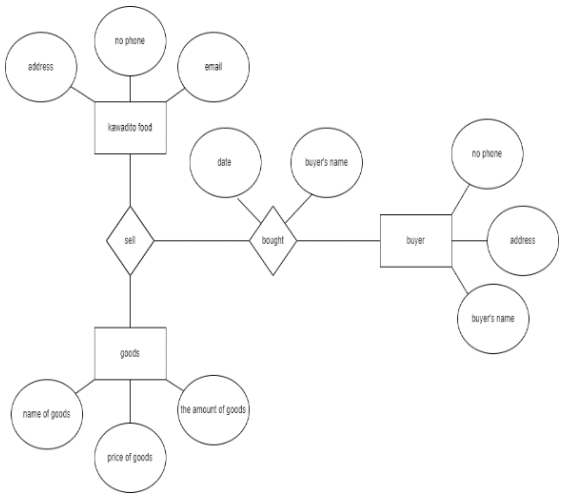

Figure 8: ER Diagram

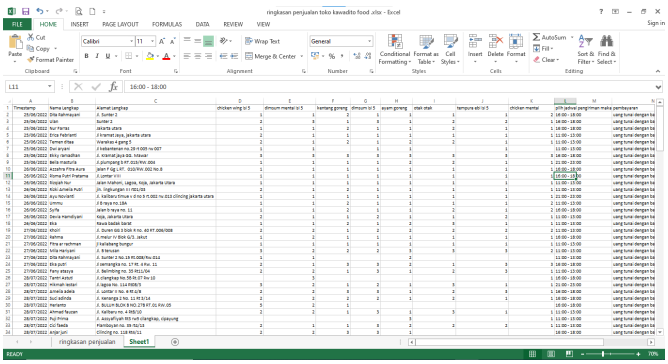

Figure 9: Kawadito Food Application Database

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REFERENCES

[1] P. M. Bican and A. Brem, "Digital Business Model, Digital Transformation, Digital Entrepreneurship: Is there a sustainable 'digital'?," *Sustain.*, vol. 12, no. 13, Jul. 2020, doi: 10.3390/su12135239.

[2] I. Wahdaniah and A. Sari, "Pembeli adalah Raja: Strategi Komunikasi Pemasaran Konvensional Warung Spesial Sambal Menghadapi Persaingan Pasar Modern," *J. Servite*, vol. 2, no. 1, p. 37, 2021, doi: 10.37535/102002120204.

[3] P. S. Hasugian, "Perancangan Website Sebagai Media Promosi Dan Informasi," *J. Inform. Pelita Nusant.*, vol. 3, no. 1, pp. 82–86, 2018.

[4] A. Arifin, "Migrasi dan Pemetaan Basis Data Menggunakan Pentaho Data Integration pada Portal Pengembangan dan Pembinaan Sumber Daya Manusia (PPSDM)," 2020, [Online]. Available: https://dspace.uii.ac.id/handle/123456789/28859%0A https://dspace.uii.ac.id/bitstream/handle/123456789/28859/16523205MahisaAgniSP.pdf?sequence$=$1&isAllowed$=$y

[5] A. O. P. Dewi, "Big Data di Perpustakaan dengan Memanfaatkan Data Mining," *Anuva*, vol. 4, no. 2, pp. 223–230, 2020, doi: 10.14710/anuva.4.2.223-230.

[6] A. Susanto and Meiryani, "Database management system," *Int. J. Sci. Technol. Res.*, vol. 8, no. 6, pp. 309–312, Jun. 2019, doi: 10.5120/179-310.

[7] Tommy, "Pengertian Data Menurut Para Ahli, Jenis-Jenis Data, & Fungsi Data," *2020*, 2020. https://kotakpintar.com/pengertian-data/

[8] "Pengertian Data Menurut Para Ahli... preview & related info | Mendeley." https://www.mendeley.com/catalogue/9ddd9bc3-8ec3-3d2d-a24d-47d52d85d61a/ (accessed May 23, 2022).

[9] I. M. Ibrahim *et al.*, "Web Server Performance Improvement Using Dynamic Load Balancing Techniques: A Review," *Asian J. Res. Comput. Sci.*, pp. 47–62, 2021, doi: 10.9734/ajrcos/2021/v10i130234.

Visual Influence of Traditional Art Characteristics in Mobile Games: Topeng Malangan as Use Case

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ABSTRACT

Regional arts that have developed from generation to generation, which have elements of belief and interpretation of community traditions, generally become the characteristics of traditional arts. One of the many traditional cultural arts in Indonesia is the Malangan Mask (*Topeng Malangan*). Malangan Mask or Malang Mask is an original mask carving art that is typical of Malang, Indonesia. It is one of the cultural heritages that still s until today. The development of Malang Mask as a work of art and culture is strongly influenced by aspects of time, environment, and technological developments, especially information technology. Currently, it is still unknown how much influence information technology has on the development of Malang Mask art and culture and their characteristics.

This study aims to identify the visual influence of traditional art characteristics when applied in mobile games. At the same time, this research was conducted to determine the impact of technological developments on the Malang Mask art. The results of this research can be useful for the community to develop and preserve traditional culture.

CCS CONCEPTS

• **Human-centered computing**; • **Human-Computer Interaction (HCI)**; • **HCI Design and Evaluation Methods**; • **User Studies**;

KEYWORDS

visual influence, cultural heritage, mobile games, topeng malangan

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1 INTRODUCTION

Arts and culture that are known by the public are relics of people who lived in the past. In ancient times people used art and culture as a means of communication, a means of survival, a tool for rituals, to use for entertainment [1]. As the times progressed, the culture began to change and became merely a legacy from our ancestors. Many people are starting to try to care for and preserve traditional cultures, some continue to carry out cultural arts in the traditional way, and some develop them following the changing times. Malang Mask is one of them. Education in Indonesia has now begun to promote the development of media as a support for education, and this is due to the shifting role of teachers at present as facilitators in the delivery of educational material [2]. With the passage of time and the advancement of existing technology, of course, art and culture also develop, and Malang Mask is no exception.

The idea to develop traditional arts into games emerged from these things. The characters in the myth and legends, their characteristics, their uniqueness, the storyline, those things are extracted and shaped into the game to attract the young generation and remember their cultural heritage. For that, it is necessary to study the relevant traditional arts and find out the appropriate interpretation in creating games related to this traditional art [3]. Interpretation consists of the art of communicating values that help promote cultural heritage or region and the creation of a reference image, allowing people to enjoy the heritage through the discovery of different cultures and cultural manifestations [4].

This study uses a mobile game as a platform in the gamification process of Malang Mask. It is because the mobile game, with its simpler and practical use, and high accessibility among the young generation make it a better choice to pick between other platforms [5]. And mobile devices offer many learning opportunities such as portability, social interactivity, context sensitivity, connectivity, individuality, and affordance to people in academic settings or non-academic settings [6].

2 RESEARCH QUESTION

To analyze if the characteristics of traditional arts might influence the visual influence and the importance of those aspects in mobile games, this study adopts a question it will strive to answer.

Question: How do the characteristics of traditional art influence the visuals in mobile games?

Sub-questions:

1. What is the visual influence of the characteristics and what are the effects?
2. What are the characteristics of traditional art and how does it affect visual perception?

3. How important is the visual influence of the game for the player's enjoyment and their intention to continue playing?

3 RELATED WORK

Yanping Xia and Yandong Lin have conducted research on character animation designs based on Dunhuang Art. They realized the similarities between Dunhuang Art and cartoon characters and carried out their research starting from character design, such as art design, integrity, and characteristics to advance the animation industry in China. They questioned whether it was possible to change the images and characters in Dunhuang art into foreign animations, which are anime characters. In traditional Chinese art, Dunhuang art has exaggerated art forms, vivid images, dynamic art images that make people feel the image is moving, imaginative style techniques that make the viewer carried away by their imagination, and storylines depicted with characters that are rich in expression. Those were analyzed and compared with similarities in the characteristics of anime which resulted that it could open a new path for Chinese animation while preserving their cultural heritage [7].

Another research was also conducted by Xian Yuan who examined the design of game characters with the characteristics of traditional Chinese culture. He analyzes game character designs combined with Chinese culture taking examples from well-known games. He researched game characters because game characters are the soul of a game, and people often judge a game by the characters in it. He researched game characters starting from their appearance, personality, and affiliation, to the music accompanying them. His research gives the result that character design is very important for the game. When designing a character, it is important to determine the style to be displayed, which is then combined with the personality of a character and their origins, followed by adequate music. When designing a character from China, then the character must use elements of Chinese culture appropriately on the character as a form of respect for Chinese culture and history [8].

Based on the research mentioned above, the visual influence of the art style and character created can made difference to the players. While it is important to maintain the original form of traditional art, some make slight changes to the appearance of the culture to attract the interest of players without changing the meaning of the cultural heritage. And some still present traditional arts as they are, and this is not a problem, because it is a form of respect for the culture and it can also attract the attention of players.

4 EFFECT OF VISUAL ELEMENTS IN GAMES

To create a great and appealing game, there is no doubt that visual aspects have a significant effect in that regard. The game has many different varieties of structures and elements, and one of them is aesthetics [9]. Humans as intelligent and ethical living beings are the only living beings who are capable to describe the word aesthetics from or into an object. Only humans can formulate certain techniques, skills, theories, and limits so that beauty can be felt and formed. Aesthetics is a branch of philosophy that studies art, the value of beauty, and human responses to it, as well as human sensitivity to art and beauty. Aesthetics is closely related to senses, expressions, imaginations, feelings, and perceptions which include of experience of everything that is perceived. The aesthetics of the game is to give emotional experience to players, engage the mind, and awaken players' emotion which will keep players continuing to play the game. The game aesthetics will be defined into 3 different principles, that is the story; the visual; and the audio [10]. The visual and the audio combined will gives an emotional experience and engage the mind while the story becomes the core followed by the audiovisuals. And thus increase the player's interest.

Theoretically, visual perception can be interpreted as the result of interpreting the meaning of information obtained through the senses [11]. The visual elements in games are perceived through the sense of sight, which is then identified to form a certain meaning, following what is seen and perceived, and each element can be perceived directly and indirectly. These elements are often defined by professional artists and researchers and applied to the visualization of games. In games, the visual elements consist of visual style, visual characters, and visual images. Those elements work together to create the visual constructive of the game and increase the player's enjoyment. Of the three elements, each of them carries a specific purpose defined in Table 1.

To build an interesting and visually engaging game, it is important to note that the visual elements are all interconnected with each other. No element developed independently, and the value of one element can highly affect another. To give an example, when choosing a certain visual style of the game, you will need to consider what kind of characteristics match up with it, and how to depict the visual image from that style. Therefore, it is necessary to select a style that blends well with how the characters are displayed, design the images that portrayed the current flow of the game, and determine the characters displayed and carried through the game. As the elements of visuals in the game, those elements have a major influence in attracting the players and awakening the players interest in the game. While the other elements of the game such as the mechanics, gameplay, and story play a big part in developing a wonderful game, the visual is the main appeal that engages the players to play the game. The strength of visual appeal is to build a visual perception of its users, hook the player's attention and allure them. And during the gameplay, the well-suited visual will bring satisfaction to the players, expand their imagination and fantasies, enchant the mind, and evoke their emotion through the visualizations presented in the game.

5 EFFECT OF THE CHARACTERISTICS OF TRADITIONAL ART ON VISUAL PERCEPTION

As the elements of visuals in the game, those elements have a major influence in attracting the players and awakening the players interest in the game. While the other elements of the game such as the mechanics, gameplay, and story play a big part in developing a wonderful game, the visual is the main appeal that engages the players to play the game. The strength of visual appeal is to build a visual perception of its users, hook the player's attention and allure them. And during the gameplay, the well-suited visual will bring satisfaction to the players, expand their imagination and fantasies, enchant the mind, and evoke their emotion through the visualizations presented in the game.

Table 1: The three visual elements of the game and their definition.

Visual Elements	Definition
Visual Style	The visual style refers to how the style of the game is classified and represented. It is known by any distinctive and recognizable way in which identified into related categories. Visual styles can be distinguished from its component, such as the realistic style with its realistic design with high pertinence.
Visual Characters	As the name suggests, this element is very much related to the overall image of the characters. Visual characters are how the character is displayed throughout the story.
Visual Images	The visual image of the game refers to the image that conveys the situation of the game. It is used to guide, direct, organize, and communicate with the player. The component of visual image, namely the visual interface of the game menu, and the visual appearance of the game title serve the purpose of communicating with the player and how the player is expected to interact with it.

Each traditional art has its own unique and different characteristics. In this study, we use Malangan Mask (Topeng Malangan) as a research subject because Malangan Mask or Malang Mask is one of the cultural heritages that have many different types and characters in each mask. Malang Mask is a traditional mask carving that originated from Malang, Indonesia. It is made from wood and used as part of the sacred rituals, worn in puppet dance, and used by storytellers when there are certain events such as weddings, celebrations, and entertainment for nobles at that time.

Malang mask has many characters, which consist of approximately 76 characters. But what people commonly know is only part of it. only 6 characters are commonly shown in the scenario of the Malang mask puppet dance, namely: Raden Panji Asmorobangun, Dewi Sekartaji, Raden Gunungsari, Dewi Ragil Kuning, Klono Sewandono, and Bapang. Malang Mask has unique characteristics that lie in the carving of the nose, eyes, lips, and the color of the mask. The color of the mask, Malang mask has 5 basic colors, which are red, white, green, yellow, and black. Where each color serves as a symbol of the mask character or the character it plays. White represents honesty, holy and virtuous nature. Yellow represents glory or delight. Green portrays the character of peace. Red depicts anger, and cunning, or it can also represent courage. Black represents wisdom. For carvings or decorations on Malang masks, it is usually in the form of an urna (mark on the forehead). Added with jasmine, kantil, and lotus jamang as decorations, and irah-irahan (headdress). Many types of Malang Masks are made based on good, evil, jest, sad characters, or irregular characters. This later will be combined with makeup and clothing to play puppet dance or a particular traditional story using a Malang Mask.

In the 6 Malang mask characters, the masked character of Raden Panji Asmorobangun, as shown in 1, determines the plot of the story conflict as the main character, identified by slanted eyes, and pointed nose downwards, visible upper teeth, and green color. His character is wise, kind, powerful, and likes to meditate. The masked character of Dewi Sekartaji, as shown in 2, who is the wife of Raden Panji Asmorobangun, is identified by her narrow eyes, sharp nose, thin lips, and white color. Her character is gentle, humble, and feminine. The masked character of Raden Gunungsari, as shown in 3, who is a friend of Raden Panji Asmorobangun, is identified by slanted eyes, pointed nose down, thin lips, and white color. His character is humble, gentle, and somewhat feminine. The masked character of Dewi Ragil Kuning, as shown in 4, who is the younger sister of Raden Panji Asmorobangun, is identified by slanted eyes, a sharp nose, and yellow color. Her character is soft, firm, and brave. The masked character of Klono Sewandono, as shown in 5, he is the enemy of Raden Panji Asmorobangun, usually identified by his round eyes, slender nose, visible upper teeth, and red color. His character is arrogant, aggressive, hard, and firm. The masked character of Bapang, as shown in 6, he is a friend of Klono Sewandono, identified by large eyes, a large nose, upper visible teeth, and red color. His character is arrogant and cunning.

As previously mentioned, humans are intelligent and ethical living beings who are capable to sense and expressing the aesthetics from or into an object [10]. As humans perceive the color they see, they think about the nature of that color, for example when they see white, the first things that come to mind are purity, holiness, and virtue. This perception happens automatically and humans utilize this in the art and designs they create a long time ago, from clothing models, building designs, and even the color of the flag. Humans make designs that are easy to understand the purpose and meaning at a glance so that the meaning of the design is conveyed to people who see it. And the same goes for traditional art such as Malang Mask. the ancients described the character of the Malang mask in detail, starting from the appearance of his face, the curve of his mouth, the shape of his eyes, and the color combination, all made with the purpose that the audience could understand the characters that were made and performed well. For example, Raden Panji Asmorobangun, the main character who has a good nature is represented on a green color basis which symbolizes peace and harmony. Coupled with slanted eyes and visible upper teeth that portray a gentle character. The characteristics of the character are shown from the look of the mask that is carved. Therefore, the appearance of the mask is adjusted to the nature of the character displayed to match the perception that will be perceived by the audience.

Figure 1: Masked character of Raden Panji Asmorobangun

Figure 2: Masked character of Dewi Sekartaji

Figure 3: Masked character of Raden Gunungsari

Figure 4: Masked character of Dewi Ragil Kuning

Figure 5: Masked character of Klono Sewandono

Figure 6: Masked character of Bapang

6 THE IMPORTANCE OF VISUAL INFLUENCE OF THE GAME FOR THE PLAYERS

For players, the first thing that attracts them to play the game is the visual presentation of the game. While it may be because of the gameplay system or certain game developers that hooks them into the game, the visual appeal is the main reason why people take an interest in the game. Thus, as mentioned earlier, the visual elements of the game need to be fulfilled and synchronized to increase its attractiveness of the game.

It is important to enhance the visual image to make it more comfortable for players. What can be done to improve it is for example by using UI that is simple and easy to understand, yet not inferior in terms of appearance, since the visual image is the visual picture is a display that is often encountered by players since the beginning of playing. It is crucial to be able to clearly describe things that players may have never seen, hence matters are set so that things commonly used to make players feel familiar, such as the settings button in the corner with the gear symbol, the exit button in the right corner top with a red cross. It is made so that players can familiarize themselves with new things they came across. As for visual style, it differs from one developer and another. While the style may belong to the same category, each developer has a unique touch on the game they develop respectively. The visual style can be ranged from pixelated art to realistic images, and each has its benefit to the game it brought. Traditional art already has its unique style from ancient times that cannot be easily replicated, but able to be improved. You can carry them as it is, change them into 2D animations, or even transform them into different art styles, even so, keep the unique trait and feature that can make them still recognized and distinguishable as a certain regional culture. The same case goes for the visual character. each game has its style of character and its mascot, making it different from other games. And cultural heritage has many of character they can offer. Many popular games take the character from famous mythology, folklore, and event from the past to the game. And it brings out joy from the players as they knew that a certain character can cast a superpower, just like the myth told. It is like looking at the visualized lore that they can enjoy to the fullest of their heart.

The purpose of visual influence is to visualize the idea from the developer to the player to attract them and invite them to enjoy the game that has been created. By improving the visual image of the game made, surely it will increase the excitement of the players because the visual plays a role in guiding the mind, emotions, and mentality towards the game and keeps them excited and interested in the game.

7 CONCLUSION

This study has concluded that it is important to build solid visual elements that increase the quality of the game and draw interest from players. Traditional arts have firm visual elements and have their historical value with a deep story and a deep connection with a particular area that can be applied as interesting game ideas. This also applies to Malang Mask, as it has many different characters and characteristics, along with many stories that can be presented. The developers will be able to further develop the games to become more educating yet fun to play. Because the main reason why people play games is that it is fun to play with. Further research and development regarding traditional art and its meaning are also needed to bring a greater way to preserve their existence for the next generations.

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REFERENCES

[1] E. Vocaturo, E. Zumpano, L. Caroprese, S. M. Pagliuso, and D. Lappano, "Educational Games for Cultural Heritage."
[2] W. Rahayuningtyas, R. T. Wulandari, A. Pramono, A. Idzwan, and H. Ismail, "Self-Efficacy in Topeng Malang Dance Learning Using Modeling Technique," 2020.
[3] M. S. Balela and D. Mundy, "Analysing Cultural Heritage and its Representation in Video Games," 2011.
[4] E. Khalid and S. Soliman, *Innovation Management and Education Excellence through Vision 2020.*
[5] A. Dissertation, *School of Information Sciences University of Tampere Dissertations in Interactive Technology*, vol. 24. 2016. [Online]. Available: http://tampub.uta.fi

[6] B. G. Jayatilleke, G. R. Ranawaka, C. Wijesekera, and M. C. B. Kumarasinha, "Development of mobile application through design-based research," *Asian Association of Open Universities Journal*, vol. 13, no. 2, pp. 145–168, Sep. 2018, doi: 10.1108/aaouj-02-2018-0013.

[7] Y. Xia and Y. Lin, "Research on Animation Character Design based on Dunhuang Art," 2019.

[8] X. Yan, "Research on the Design of Game Character with the Chinese Traditional Culture Characteristics," 2016. [Online]. Available: www.ijbssnet.com

[9] M. Ahmad, "Categorizing Game Design Elements into Educational Game Design Fundamentals." [Online]. Available: www.intechopen.com

[10] A. Mortensen, "The art of the game-how game aesthetics and visual perception affect the player involvement in videogames."

[11] D. Pratama, W. Gunarti, W. Wardani, and D. T. Akbar, "The Visual Elements Strength in Visual Novel Game Development as the Main Appeal," *MUDRA Journal of Art and Culture*, vol. 33, no. 3, pp. 326–333, 2018, [Online]. Available: https://sweetchiel.itch.io/new-nusantara-legend-of-the-

Development of Internet of Things Cloud Shop Floor Machining Manufacturing System

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ABSTRACT

The fourth industrial revolution was triggered by the development of information and communication technology, where the technology base is intelligent automation with decentralized control and advanced connectivity supported by IoT (Internet of Things). For the manufacturing industry, the new technology allows production systems to carry out flexible mass customized production with flexibility in production quantities. By using the Industry 4.0 concept for manufacturing systems and Manufacturing Execution System (MES), this research develops cloud IoT on the shop floor of the machining manufacturing system. The data obtained from manufacturing machines and shop floor activities are stored in a database that is connected via IoT machining workstations and IoT work stations order release. Using the IoT device that was created, the machining work station IoT device is a device that sends machine activity data online, while the order release station IoT device is a device that sends job data online to the machining work station. Cloud IoT shop floor of the resulting machining manufacturing system, placed on the campus website. Cloud IoT is capable of receiving and sending order release workstation and machining workstation data to the database for further processing and display online.

Additional Keywords and Phrases: Internet of things, Manufacturing industry 4.0, IoT cloud, Shop floor.

CCS CONCEPTS

• :; • **Social and professional topics** → Professional topics; Management of computing and information systems; System management; Centralization / decentralization;

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1 INTRODUCTION

The fundamental development of Industry 4.0 is the availability of relevant information that can be accessed from anywhere and anytime. To enable this to happen, all the resources involved such as human resources, objects, and systems must be dynamically integrated, organized, real time, and must provide optimal added value [1]. Since its introduction at the German Hanover fair in 2011, Industry 4.0 has become a topic of discussion in the research, academic and industrial communities on various occasions. The main idea is to take advantage of the potential of new technologies and concepts such as the availability and use of the internet and the Internet of Thinks (IoT), integration of technical processes and business processes in enterprises, digital mapping and virtualization of the real world, as well as smart factories including industrial production tools smart production and smart products [2]. Manufacturing is the backbone of modern society, so the advancement of information and communication technology and the use of IoT, brings a whole new scenario in the industry called smart factory. Smart factories carry out manufacturing practices by utilizing data networks as well as information and communication technology to manage manufacturing system operations [3].

Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES) are two of the most important information systems that can provide a good overview of the factory floor, as well as a good fit for long-term planning. ERP as an evolution of Manufacturing Resource Planning (MRP) can be seen as a tool that generates information in production systems and other systems within a company. ERP & MES are used to control production planning and logistics functions. Since MES is the software closest to the factory floor and interacting with it, many companies are interested in building distributed information systems capable of producing an integrated flow of information. This system integration also provides the ability to build a database structure which further enables more flexible data analysis and facilitates data visualization for the decision-making process [4].

Currently, researchers and practitioners are still conducting research to create software specifications and appropriate conceptual models for MES [5]; [4]. These studies were conducted using case studies in companies. Based on the concept of Industry 4.0 for

manufacturing systems and MES, this paper describes the results of research on the development of the Industry 4.0 model for the machining manufacturing industry, which consists of three clouds, namely [6]; [3]: IoT cloud, Data-Network cloud, and Application cloud (Analytics & Visualization). Developed machining manufacturing system shop floor cloud model, using cases from the machining industry of molds, dies, and precision components makers. This research implements cloud technology on the shop floor of the machining manufacturing system carried out in mechanical workshops. Cloud IoT accommodates shop floor activity data sent via IoT devices. The developed IoT cloud is part of the Industry 4.0 cloud machining manufacturing system which will be further developed.

2 INDUSTRY 4.0 IN MANUFACTURING SYSTEMS

2.1 Industry 4.0

Currently, the industry is in its fourth industrial revolution triggered by the development of Information and Communication Technology (ICT). The technology base is intelligent automation of cyber-physical systems with decentralized control and advanced connectivity using the Internet of Things (IoT). The consequence of this new technology for industrial production systems is the reorganization of the classical hierarchical automation system into a self-regulating cyber-physical production system that allows for flexible individual mass production and flexibility in production quantities [2].

Industry 4.0 is a challenge in the industrial world that must be faced. It is seen as important in the ability to adapt to market and consumer demands. In addition, more flexible and more decentralized production and technology acquisition are becoming an important part of this fourth industrial revolution [4]. The 4th industrial revolution is based on the integration of business and manufacturing processes as well as integration within the enterprise chain. In Industry 4.0 the technical aspects are met with the application of Cyber Physical Systems (CPS), Internet of Things (IoT), and Internet of Service (IoS) to industrial production lines. The ERP system has become an Industry 4.0 system that uses IoT, IoS, and CPS [4].

The machines in Industry 4.0 factories are CPS, which is a physical system that is integrated with ICT components. The system is an autonomous system that can make its own decisions based on machine learning algorithms and real-time data retrieval, analytical results, and log successful past behavior. The machines in Industry 4.0 factories use programmable machines (CNC (Computer Numerical Control) and NC (Numerical Control)), with mostly mobile agents and self-optimizing robots. In Industry 4.0, production elements in addition to their physical representations also have virtual identities, namely data objects stored in the data cloud. These virtual identities can include various data and information about products (from documents to 3D models), individual identifiers, current status data, historical information, and measurement/test data [2].

2.2 Manufacturing System Software

Software is critical to the operation of Industry 4.0 smart factories. Figure 1 illustrates the pyramid structure of the software supporting modern manufacturing systems. At the business level, Enterprise Resource Planning (ERP) is implemented. ERP supports enterprise-wide planning such as business planning, supply chain management, sales and distribution, accounting, human resource management, and the like. In traditional ERP, the decision process is centralized at the highest level in the automation pyramid. Most of the ERP system solutions available do not support rapid adaptation of unplanned events in production planning [2].

ERP is an integrated enterprise computing system. Companies can automate the flow of information, resources, and all company functions in the database. ERP integrates databases, applications, and interfaces throughout the company [4]. The second level in the traditional automation pyramid is the Manufacturing Execution System (MES). MES supports production reporting, scheduling, delivery, product tracking, maintenance operations, performance analysis, workforce tracking, resource allocation, and the like. This includes aspects of shop floor management and communication with company (business) systems. Most of the software solutions available in the market are still centralized and are not distributed to shop floor elements. This becomes a major limiting factor when flexibility is required due to dynamics of customer order flow and/or changes in the production environment or shop floor configuration [2].

MES will determine the foundation of the Industry 4.0 paradigm. This system will eliminate information stacks, introduce knowledge management practices, and introduce data visualization mechanisms. The flow of information with this system can flow more easily and be able to make decisions faster [4]. MES is an information system that connects monitors and controls to manufacturing systems, and connects data flows that occur in factories and production floor systems. The main objective of MES is to ensure that manufacturing operations are carried out effectively and increase production yields [5]. The next operative level is process level control based on the Supervisory Control and Data Acquisition (SCADA) control system architecture followed by controllers at the machine/device level such as Programmable Logic Controller (PLC), robot controllers, and other controllers. The last level of the automation pyramid is the machine/device level. Contrary to the top two layers, this level has a naturally distributed level of control.

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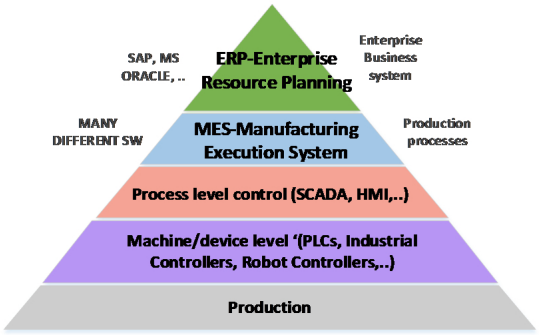

Figure 1: Pyramid of automation in modern production systems [2]

automation pyramid is the machine/device level. Contrary to the top two layers, this level has a naturally distributed level of control.

ERP and MES represent the basic software in the company, and are used since the nineties. Both systems usually have a modular structure but are centralized in operation, so that the dynamic adaptation of the production plan is limited. However, the conventional ERP and MES systems that have been implemented should not be seen as the main obstacle in introducing the concept of Industry 4.0, but rather as a first step towards Industry 4.0. The introduction of MES requires advanced ICT infrastructure at the shop floor level, and this is also a prerequisite for further development towards smart factories. The next important issue is the integration of information between ERP, MES and other software used in companies such as customer relationship management (to help manage relationships with outsiders) and business intelligence (for business analysis purposes). The problem of integration of databases and communication protocols, as well as vertical and horizontal integration between all elements, is something that needs to be solved [2].

2.3 ERP and Shop Floor Integration with MES System

There Shop floor integration is an important requirement in implementing the Industry 4.0 concept. There are two things to do with shop floor integration. The first is the integration of all machines, systems and user interfaces (including central ICT systems with MES level). MES must ensure the product is made correctly. In this case the lower level layer/shop floor integration layer has to handle the process. This layer manages the MES on all details of shop floor control and communications. The second is the communication system on the shop floor. The goal is to provide an industry standard interface with the result of the integration of the production floor in the form of controlling production activities.

An ERP system contains information about inventory, customer demand, and MES controls that show how to build it. Thus, integrating the two can help improve operational efficiency and allow organizations to be more flexible. In addition, the real-time exchange of information between the business layer and production layer can help improve overall efficiency, reduce cycle times, and management can get more visible information and help improve the quality of decision making [5].

MES is the software that is closest to and interacts with the shop floor system. MES distributes information with an integrated information flow. This system also provides the ability to build a database structure that allows for more flexible data analysis and facilitates the visualization of data that influences the decision-making process [4].

3 METHODOLOGY

3.1 Model I_Manuf_4.0

The Manufacturing Industry 4.0 that will be developed consists of three clouds, namely: IoT cloud, Data-Network cloud, and Application cloud (Analytics & Visualization). The activities in these clouds are data source (source), data collection (collection), data processing (processing), data storage (storage) and application (application). In I_Manuf_4.0 clouds, data sources are obtained from equipment, products, operators, information systems and networks. Data is acquired using smart devices capable of communicating to collect, transmit, and act. Furthermore, data from different sources is collected in various ways, including historical data, real-time data and data from the web. Historical data is the result of storing data from time to time to describe the development or trend of an event. Real time data is the result of a processing system whose processing uses real time and is designed to handle workloads whose conditions can change. Web data is a repository that stores large amounts of raw data in its original format, including structured, semi-structured, and unstructured data. Data processing refers to a series of operations performed to find knowledge from a large amount of data. Data must be turned into information and knowledge for producers to make informed and rational decisions.

3.2 Manufacturing System Activity Model

The manufacturing system activity model in this study includes [7]: Manufacturing Management, Manufacturing Engineering, Manufacturing Planning and Control, and Manufacturing Production which interact in one system. Data from consumers is received by Manufacturing Management which is handled by Order Management, Cost & Time Estimation, and Product Costing, which then forwards the information to Manufacturing Engineering for process evaluation, design, and process planning. In addition, Manufacturing Management also provides information to Manufacturing Planning & Control for planning and scheduling (planning & scheduling) as well as setting down orders to the production floor by the Shop Order Release station, before the production process is carried out. If the production process is carried out, then monitoring is carried out to determine the progress of the manufacture.

3.3 IoT Devices and Systems Machining Workstations and Workstations Shop Order Release

Similar to the device discussed in [8], the IoT devices developed in this study consist of: current sensors, RFID (Radio Frequency Identification) and Node MCU modules, which are applied to machining work stations and shop order release work stations. RFID

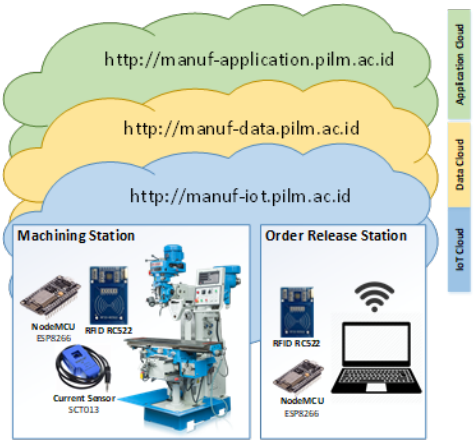

Figure 2: Model clouds of machining shop floor system

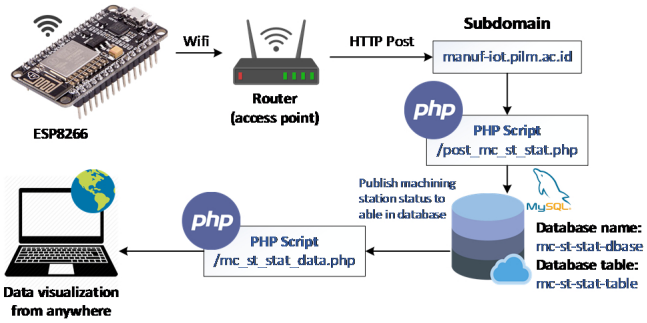

Figure 3: IoT cloud mechanism schematic

and sensors that are applied to manufacturing machines are processed by the Node MCU module which is connected to the internet to transmit data via an access point/router. The Node MCU used serves as the brain for processing the IoT device system. During the operation of the machine, the data related to the activity of the machine is detected by the sensor which is then sent and stored in the database. Likewise, the work that has been completed by the machining work station is sent by the order release workstation and saved to the database. Thus, the machines at the work station and the order release station are connected to each other and provide data/information through the internet network.

3.4 Model Clouds Shop Floor Machine Manufacturing System

The cloud system works by using the internet domain as a server to store and process data. This system allows users to connect to the internet connected to the program to run applications that store and process data and display information. The production floor cloud model of the machining manufacturing system in this study can be shown in Figure 2. The data obtained by the IoT device of the order release workstation and the machining workstation are sent and stored in the database. The schematic of the IoT cloud mechanism for the shop floor of the machine manufacturing system developed is shown in Figure 3. Node MCU, sensors, and RFID function as IoT devices. The data obtained is uploaded to the manf-iot.pilm.ac.id domain using the HTTP protocol over a network that uses a router (access point). Furthermore, the data is managed by the PHP script post_mc_st_stat.php to be stored in the MySQL database. To perform data visualization, done by PHP script mc_st_stat_data.php.

4 RESULTS AND DISCUSSION

4.1 Developed Manufacturing System Activity Data and Model

The scope of development carried out in this research is the Manufacturing Execution System (MES) in the scope of Manufacturing Planning & Control (in this case only Shop Order Release work stations) and Manufacturing Production (in this case only machining work stations). The data involved starts from the results of the Planning & Scheduling function in the form of a Plan Order Release, as well as supporting data in the form of a Process Planning Sheet as a result of Manufacturing Engineering. To support the activity of order release work stations and machining work stations, database tables have been developed to support and during production activities. The database design built in this study refers to the literature [4], real cases found in industry, and the needs in the workshops of the Morowali Metal Industry Polytechnic. The data obtained from the order release station and the machining work station are sent and loaded into the database table that has been provided. The database table of order release work stations and machining work stations are connected and complement each other during production activities. The details can be shown in the schematic in Figure 4.

The order release database table contains data that has been written and loaded by the dispatcher through the order release work station. In addition to writing work order data on the RFID card, the data is also loaded in the order_release_table database table via IoT devices. Furthermore, reading the RFID card on the IoT device placed at the machining work station. The data is then loaded into the machine state database table mc_st_stat_table at the time the machine starts. Machining activities are recorded online and loaded into the mc_st_stat_table database table during the activity. After the production activities are completed at the machining station, then the order_release_table database table data is completed according to the production activities completed by the order release work station.

In addition to the main database tables above, the supporting database tables that have been developed are: pp_table (process plan table), operator_table, mc_table (machine table), and plan_or_rel_table (plan order release table). The supporting database table was developed to support the order release data table. The data involved starts from the results of the planning & scheduling function in the form of a plan order release, as well as supporting data in the form of a process plan sheet. The supporting database table can be shown in the schematic of Figure 5.

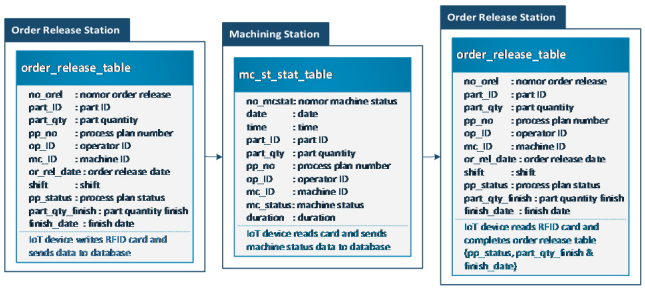

Figure 4: Order release database table and machining status

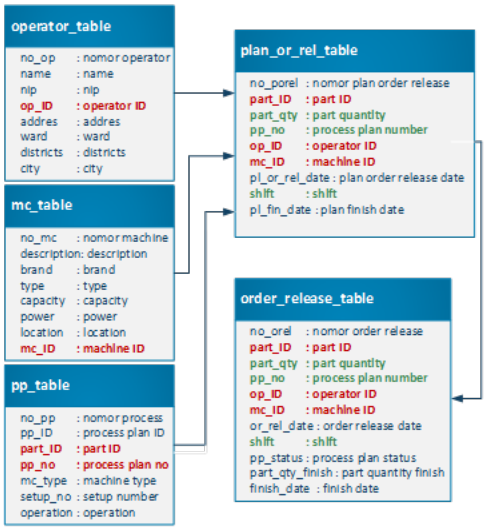

Figure 5: Supporting database table

4.2 Design and Build of Order Release Workstations and Machining Workstations

The prototype of IoT devices in this study uses Node MCU and RFID modules as well as LCD (Liquid Crystal Display) which are applied to machining work stations and order release work stations. The machining workstation IoT device is equipped with an electric current sensor. The Node MCU device functions as a microcontroller capable of sending data to the internet via an access point/router. The electronic circuit design of the order release station IoT device is shown in Figure 6.

At the work station order release the device works when it lowers the job data to the machining operator before heading to the machining work station. Work orders and job data are given through the RFID card by filling out the dispatcher via a serial monitor and recording it on the RFID card attached to the IoT device. After filling in the RFID card, the data is uploaded and recorded in a database via the internet. The IoT device used at the order release workstation is shown in Figure 7. IoT devices on machining workstations are similar to devices on order release workstations. The device uses an RFID module and Node MCU and is equipped with an electric current sensor that functions as a machine activity reader that is used when the machine is operated. The electronic

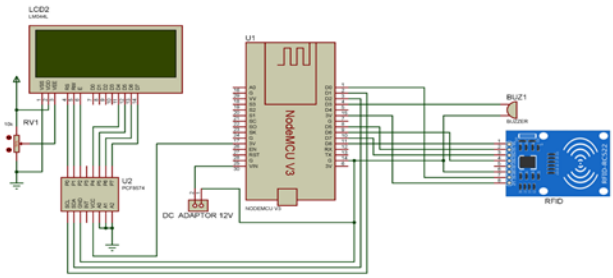

Figure 6: Order release workstation electronic circuit design

Figure 7: Order release workstation IoT device

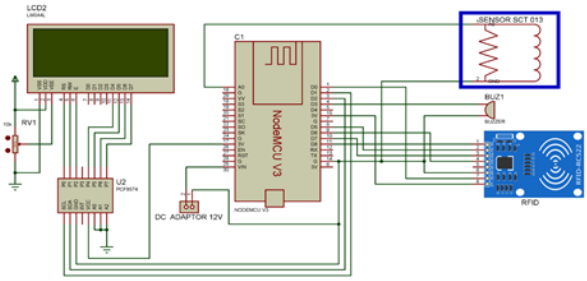

Figure 8: Machining workstation electronic circuit design

circuit design of the machining workstation IoT device is shown in Figure 8.

The Node MCU used in the machining workstation IoT device serves as the system processing brain. During machine operation, data related to machine activity is detected by sensors which are then uploaded and recorded in the database. Likewise, the work that has been completed by the machining work station is reported by the operator to the order release work station. The job data is read from the RFID card, the job status data is inputted by the dispatcher, then the data is uploaded and recorded in the database. Thus, the machines at the machining work station with the order release work station are connected to each other and provide data through the internet network. The IoT device on the machining workstation is shown in Figure 9.

4.3 Machining manufacturing system shop floor cloud development

Based on the machining manufacturing system shop floor cloud model that has been described in the research methodology, the machining manufacturing system shop floor IoT cloud in this study

Figure 9: Machining workstation IoT device

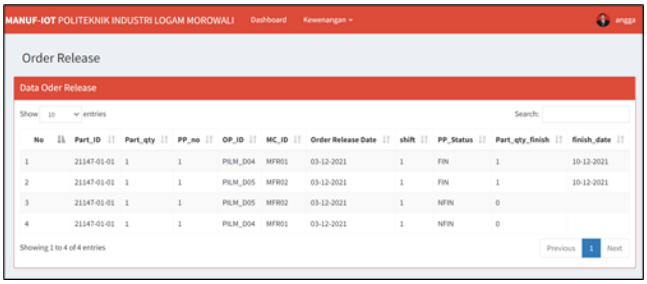

Figure 10: Display order release data

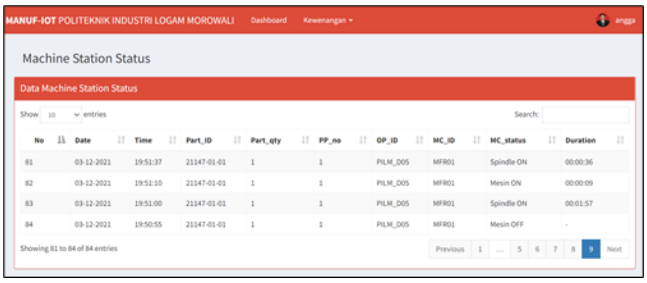

Figure 11: Machining workstation data display

uses the internet domain manuf-iot.pilm.ac.id as a server to store and process data. This system allows IoT devices located on machining work stations and order release work stations to be connected to the internet via a network that uses a router (access point). To send and record data to database using HTTP protocol. Data entry and delivery activities by dispatchers on order release workstations are sent to the order_release_table MySQL database. To visualize the stored data, it is done by the PHP script order_release_data.php. The visualization of data that has been successfully sent and saved to the database is shown in Figure 10 as follows.

Similar to order release workstations, data from machining workstations obtained from manufacturing machines are stored in a database via the internet. Node MCU functions as a data collector from manufacturing machines, and sends it to the manuf-iot.pilm.ac.id domain using the HTTP protocol over a network that uses a router (access point). Furthermore, the data is managed by the PHP script post_mc_st_stat.php to be stored in the MySQL database mc_st_stat_table. To visualize the stored data, it is done by the PHP script mc_st_stat_data.php. The visualization of data that has been successfully sent and saved to the database is shown in Figure 11 as follows.

5 CONCLUSION

This research produces IoT devices and cloud IoT shop floor machining manufacturing systems involving order release work stations and machining work stations. The test results show that the data obtained from manufacturing machine activities and production floor activities are stored in a database that is connected through the IoT device for the machining work station and the IoT device for the order release work station. The machining work station IoT device is a device that online sends production machine activity data. Meanwhile, the order release workstation IoT device is a device that sends job data online to the machining workstation. Cloud IoT shop floor of the resulting machining manufacturing system, placed on the campus website. The developed IoT cloud is capable of receiving and sending order release workstation and machining workstation data for analyzing order release and productivity analysis of shop floor.

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REFERENCES

[1] Reimund Neugebauer, Sophie Hippmann, Mariam Leis, Martin Lendherr. 2016. Industri 4.0 – From the perspective of applied reserach, CIRP-CMS 2016, Procedia CIRP, No. 57.
[2] Andreja Rojko. 2017. Industry 4.0 Concept: Background and Overview, Special Focus Paper, International Journal of Interactive Mobile Technologies (iJIM), Vol. 11, No. 5.
[3] Xifan Yao, Jiajun Zhou, Yingzi Lin, Yun Li, Hongnian Yu, & Ying Liu. 2019. Smart manufacturing based on cyber physical systems and beyond. Journal of Intelligent Manufacturing, 30(8), 2805–2817.
[4] Juliana Salvadorinho & Leonor Teixeira. 2020. Shop floor data in Industry 4.0: study and design of a Manufacturing Execution System, Proceedings Conferência da Associação Portuguesa de Sistemas de Informação (CAPSI'2020).
[5] BMTN Rathnayaka, Indika de Silva, & Bhanuka Senavirathne. 2019. Industry 4.0: ERP and Shop Floor Integration with Manufacturing Execution System (MES) in Sri Lankan Manufacturing Organizations, Proceedings of 12th International Research Conference 2019, General Sir John Kotelawala Defence University (KDU), Srilangka.
[6] Fei Tao, Qinglin Qi, Ang Liu, & Andrew Kusiak. 2018. Data-driven smart manufacturing, Journal of Manufacturing Systems, Volume 48, Part C, July 2018, Pages 157-169.
[7] Isa Setiasyah Toha, H. Taroepratjeka, Mulyowidodo & Samadhi. 1996. CIM-LSP Sistem Manufaktur Terintegrasi Komputer Laboratorium Sistem Produksi TI-ITB, Jurnal Teknik dan Manajemen Industri, Nomor 16, Desember, pp. 7-22.
[8] Senapati C. Adisasmito,Pradipta Deffinika Pamungkas, & Anas Ma'ruf. 2021. Real-time Monitoring Design for Make-To-Order Industry, Proceedings International Conference on Informatics, Technology and Engineering 2021 (InCITE 2021), Surabaya, 25-26 Agustus 2021.

IoT-based enterprise architecture model for monitoring safety of drugs supply to the patient at hospital

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ABSTRACT

Hospitals as a triage system need IoT improvement to help healthcare professionals manage their drug data. Nowadays, IoT is very close to humans to help human minimize their human error nature at work. Hopefully, IoT improvement will omit medicine errors. The author decides research variables and research indicators to set these research goals. First of all, risk will be mapping, after that the business map outcome of IoT implementation will be explain to see scope of this research. After all, the enterprise architecture model will give detailed information about the IoT improvement for monitoring the safety of drugs supply at the hospital. This research purpose is to keep the patient safety of the hospital, and help professional healthcare manage the drugs, and avoid human error in terms of giving the drugs to the patient.

CCS CONCEPTS

• ; • **Computer systems organization** → Architectures; Other architectures; Special purpose systems;

KEYWORDS

Drugs, IOT, medicine error, medicine, medicine IOT

ACM Reference Format:

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1 INTRODUCTION

Hospital requires very high safety procedures because it correlates with patient's safety, therefore, IoT systems need to prevent human error. IoT systems could help healthcare professionals in doing operational excellence. Medicine is essential and requires zero fault in selecting, procuring, distributing, and using the drug. Hospitals should separate the drug based on the category for medical purposes. The stock of medicine also needs using FIFO (First In First Out) system and FEFO (First Expired First Out) system. Using those two systems will hopefully minimalize medicinal errors. [1] Seven principles to give a patient medicine are correct dosage, correct route, correct patient, correct time, correct documentation, correct information, and correct medicine's name. [2] Community pharmacies exhibited dependable structures fantastically withinside the exhibit for stopping and detecting drug or dose choice mistakes while filling prescriptions for warfarin. Reliability changed into pushed via way of to be had technologies, together with barcoding, computerized shelling out, scanned prescription images, and computer-generated pill images. If barcoding generation changed into used verification, selecting the incorrect drug while filling a warfarin prescription at the same time will surely attain sufferers every four years from U.S. pharmacies. Alternatively, incorrect dose choice has been expected to attain sufferers from 24 instances every year. Increasing computerized shelling out of warfarin to 50% and the frequency of affected person counselling to 80%, reducing the chance of incorrect drug choice every twenty years and the wrong dose will be decided and disbursed every five years amongst U.S. pharmacies. [3] The author found the other paper as reference and gave a solution that automatic drug dispensers have gained wide acceptance by nurses in a variety of clinical settings despite disruptions in the workflow. Pharmacy staff and assistants had similar experiences with the system, although the pharmacy assistants were more positive. Adaptations that improved access were more acceptable to nurses inwards than in specialized areas, prompting consideration of redesigns to enhance efficiency. Staff noted that drug dispensers use slowing the drug delivery processes due to queues and other factors affecting the workflow. [4]

On the other hand, somebody tries to using IoT to control the usage of drugs and drug's reaction to the patient. The system offers an innovative IoT drug identification system and remote knowledge system. Drugs are identified using interchangeable drugs mobile devices and taking into account of the emerging NFC technology and legacy identification solution such as a barcode. Someday the drug will be identified and this information will be sent to the pharmacy Intelligent information system where it decomposes active ingredients which are matched to the patient's allergic profile and electronic medical records to identify the potential reactions.[5] Since maximum mistakes arise on the prescribing step, Computerized Prescription Entry (CPOE) with affected person-specific selection guide is a doubtlessly powerful intervention to enhance affected person's safety. Common prescribing mistakes include incorrect medicine or dosage form, wrong dose calculation, failing to test for allergic reactions, and no longer adjusting the dose in sufferers with kidney or liver dysfunction. CPOE structures paintings by (i)will

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Table 1: Data of risk causes, risk impact, risk element and risk category.[8]

No.	Citation	Risk causes	Risk Impact	Risk Element	Category
1.	The nurse gives the wrong drugs to the patient, impacting side effect to the patient; a patient feels dizzy and vomit several times.[9]	The nurse give drugs for other patients to another one.	The old female patient feels dizzy and vomit.	- No Labelling - No checking for the patient data - No relevancy data - Negligent healthcare professional.	Wrong Drugs Dispense
2.	Public hospital in Lumajang wrong gives drugs for suspected COVID 19 patient.[10]	The nurse gave the suspected COVID – 19 patient the wrong drugs.	The suspected COVID 19 male patient hardly to breath.	- Negligent healthcare professional. - No relevancy data - No checking for the patient data	Wrong Drugs Dispense
3.	RESEARCH NOVELTY	The human factor has contributed to the risk of the wrong dispense of drugs to the patient.	Make a side effect, dizzy, vomit, hard of breath, even could make someone death.	No relevancy of the data No accuracy of the data No consistency of the data	IoT to help no error in data transfer. So the data will be on the correct path.

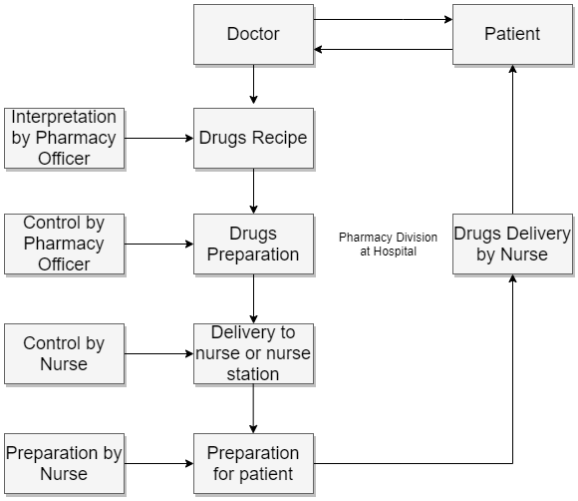

Figure 1: Flowchart of drugs delivery at the hospital. [7]

make sure that the order is legible and complete, which includes all necessary records which include dosage, course of administration, and dosage form; (ii) revision for problems which include allergic reactions and drug interactions; (iii) offer dose adjustment calculations which are primarily based totally on scientific traits which include weight or kidney function; (iv) Verify suitable reference laboratory results; which include platelet remember and global normalized ratio for sufferers receiving anticoagulants; (v) Calculation of drug and laboratory interactions, which include: B. Advising the prescribed health practitioner of low attention of potassium while prescribed digoxin; and (vi) replacing the prescriber with the ultra-modern records on medications, which include: B. the want to keep away from rofecoxib afterwards. [6]

Figure 1 explains about drugs supply flow, the doctor will examine the patient, and finds symptoms, after that, the doctor will write a recipe which will be interpreted by the pharmacy officer and the drugs will be prepared by the pharmacy officer. After the preparation of the drugs, the drugs will be delivered to the nurse station, and the nurse will prepare the dosage based on the requirement from the doctor. After making sure all the things are complete, then drugs will be delivered by a nurse to the patient. At the time nurse will also explain complete information to the patient

Table 1 about Research novelty will be using data management as an application, but using IoT sensor to make verification would minimize the risk. The verification will be done by two-division at the hospital which are pharmacy and nurse, after that, the patients need to verify that they receive the correct recipe and dosage of the drugs given by the nurse. This will be giving a contribution in patient safety at hospital.

2 METHOD

The case study can be used to identify incidents, test theories, and create a new theory.[11] The case study methodology is based on qualitative analysis and focuses on the observation of a social phenomenon, individual, organization, group or institution. This method allows for a deeper investigation of the incident and its causes. This method can also determine the course of some incidents. Studying risk factors and risk elements can do a good risk analysis. [12] The research method will be observating and collecting data, several accidents report will be analyzed. After that, the author will make an enterprise architecture model using TOGAF (Figure 2). The business layer, application layer and technology layer will be the focus of this research.

Figure 3 The IoT based for monitoring the safety of drugs supply to the patient at the hospital will change the workflow process of drugs supply because this architecture model will be added in technology layer. IoT improvement needs to minimize the wrong

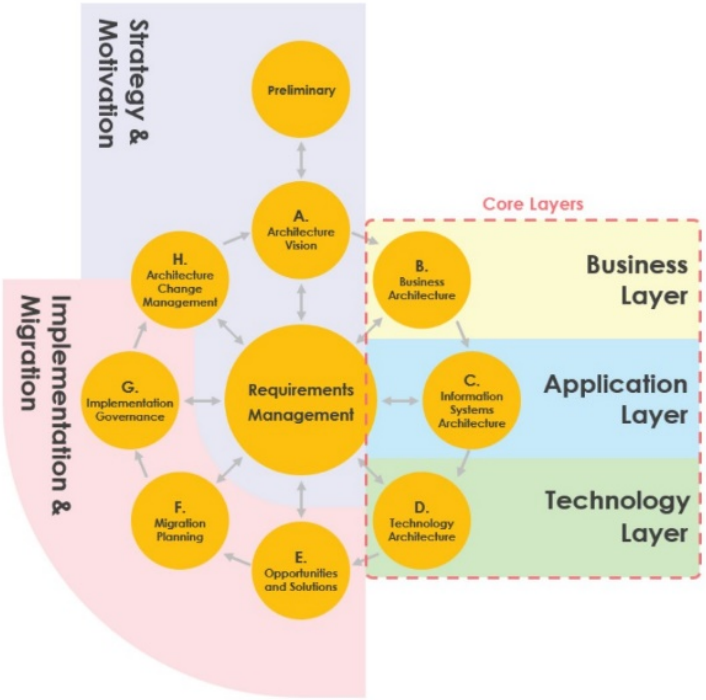

Figure 2: TOGAF architecture model [13]

dispense and keeps the data accuracy, relevancy and consistency. The patient's fast recovery will be the target of this process with operational excellence.

Table 2 about Business map's outcome defines the impact of improvement to the actor, and the explanation about the process will be improved with this IoT system to achieve the benefit promises of using IoT system improvement. The next step of this method is to decide the research variable with the research indicator. The research variable is the element of the process that supports the changing of the process. The research indicator will give a value of the changing process whether the improvement is good or not.

Table 3 Data reputation will achieve the goal if the patient gets the correct dosage. Data consistency will achieve the goal if the distribution of the drugs is on the right path. Data's completeness will achieve the goal if the drugs are distributed to the correct patient. Data currency will achieve the goal if the drugs are supplied to the patient on time. Data timeliness will achieve the goal if the documentation is correct. Data accuracy will achieve the goals if the drug has corrected information. Data interpretability will achieve the goal if the drugs name is interpreted by the pharmacy officer with the drugs name given to the patient which has the correct medicine's name.

3 RESULTS AND DISCUSSION

The scope of architecture in business architecture, application architecture and technology architecture. Research variables and research indicators give a point of view about the needs covered by information technology. Therefore, the drugs dispense need touch of technology. To achieve the goals, the author starts by making enterprise architecture model for safety and monitoring drugs supply in healthcare facilities. Bases on the risk of drugs supply, and TOGAF as an open-source architecture framework, the author start to make architecture vision, architecture capabilities and architecture model.

3.1 Architecture vision

Table 4 define the architecture vision based on risk and risk category to define capabilities needed. Usually, the risk happens because of human error, which technology could minimize. The capabilities need to be defined first to know the technology needed to reduce the risk. Analysis of patient attributes is required to recognize the patient and give the correct therapy to the patient. Research of medical records is also needed to know the history of treatment given to the patient. Analysis of drugs attributes is used to see the type of drugs given to the patient. Analysis of drugs consumes monitoring to provide a transparent effect to the patient and provide data to decide what needs to do next. Analysis of inventory data gives precise data about the labelling, stock and flow of drugs supply.

3.2 Business architecture, application architecture and technology architecture

Table 5 explain about capabilities need. Business architecture based on need is described in detail to get the exact architecture design, the application based on business architecture is made to realize the business architecture, and the technology architecture supports

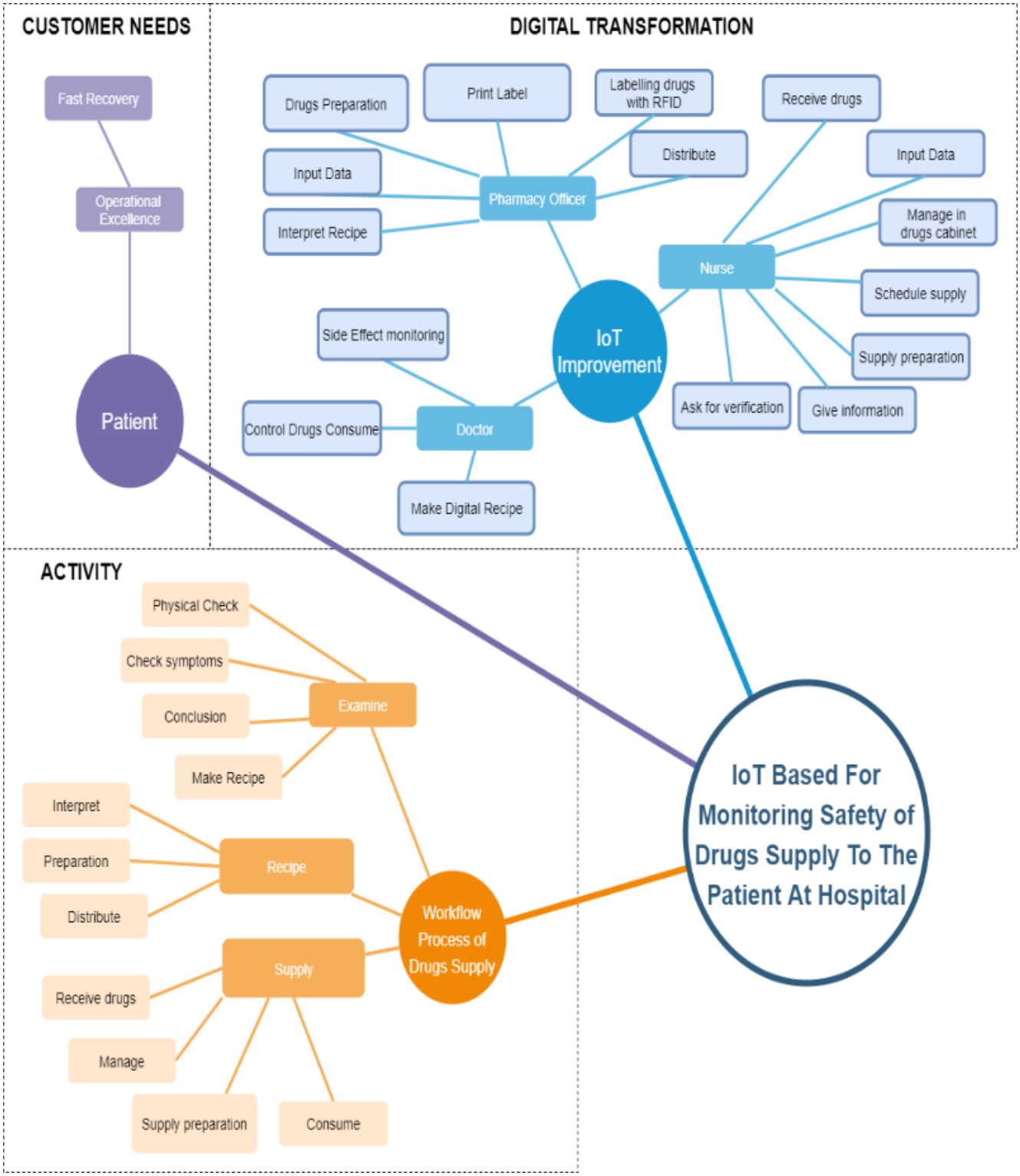

Figure 3: Business map outcome of IoT implementation

Table 2: Description of the business outcome of IoT implementation.

Improvement	Description	Benefits
Digital Transformation		
Doctor	The doctor will make a digital recipe and control drugs use to the patient while monitoring the side effect.	The doctor, as a data owner, should give relevant data.
Pharmacy Officer	The pharmacy officer will receive a digital receipt and interpret the recipe; after that pharmacy should complete the data of the dosage and name of the drug. After that, input the data of the patient based on medical record number. Preparation of the drugs and putting an RFID label on a drugs container. So the drugs are ready to distribute	Pharmacy as a data accountable has responsibility for accuracy of the data, with this RFID system will minimize missing data consistency.
Nurse	Receive the pharmacy drugs, input data, and schedule the supply. After that, they could put the drugs into the drugs cabinet while waiting for the schedule to supply to the patient.	Minimize missing data, and make sure the data is still accurate.
ACTIVITY		
Examine	The patient will be physically checked while trying to analyze the symptoms and conclude before making a digital drugs recipe.	It is easier to transfer the data, and data has consistency during the transfer with the IT system.
Recipe	The digital drugs recipe is interpreted by the pharmacy officer and prepared by the pharmacy officer, including input data of the patient, make sure dosage and ingredients, after that the drugs are ready to distribute.	Ensure accuracy of the data and keep the consistency of the data transfer to the other division.
Supply	The nurse receives drugs from a pharmacy officer, manages the drug data, and prepares the supply dosage, schedule, and patient data. When the schedule is reached, the nurse gives the drugs to the patient.	Human error will be reduced by the consistency of data of giving drugs to the patient.
CUSTOMER NEEDS		
Patient	The patient in lousy condition doesn't want to have another problem, even consuming the wrong dosage and ingredients. The system will match drugs ingredients with the patient's medical record history, whether contraindicated.	A patient will get correct data about drugs they consume and verify when they have already finished them.

Table 3: Research variables and research indicators

Research Variables	Research Indicators
Data Reputation	Correct dosage
Data Consistency	Correct route
Data Completeness	Correct patient
Data Currency	Correct time
Data Timeliness	Correct documentation
Data Accuracy	Correct information
Data Interpretability	Correct medicine name

Table 4: Architecture vision

Risk	Risk Category	Capabilities
Drugs are given to the wrong patient	Human error	1. Analysis of patient attribute 2. Analysis of medical record data
Wrong drugs type gives to the patient	Human error	1. Analysis of drugs attribute 2. Analysis of drug consumption monitoring 3. Analysis of inventory data

Table 5: Capabilities, Business Architecture, Application Architecture, Data Architecture and Technology Architecture.

Capabilities	Business Architecture	Application Architecture	Technology Architecture
Analysis of patient attributes	Digital complete data of the patient.	Access digital patient data and digital confirmation by the patient.	Mobile apps, RFID reader and label.
Analysis of medical record data	Digital medical record data	Access digital historical health condition of the patient, and report the progress of patient health in digital.	Mobile apps
Analysis of drugs attribute.	Digital data of drug ingredients	Scanning and showing information about the drugs given to the patient and comparing it with the medical record data.	Mobile apps, RFID reader and label.
Analysis of drug consume	Drugs side effect monitoring by a digital system	Drugs side effect monitoring and healing progress.	Mobile apps
Analysis of inventory data	Drugs labelling and control by IoT system	Purchase requisition system, input drugs information, drugs labelling, and distribution monitoring by scanning the label of the drug.	Mobile apps, RFID reader and label.

the business architecture and application architecture. The need to analyze patient attributes make complete digital data of patient as a supporting and access digital patient data and digital confirmation by the patient is needed in application, to make sure the same drug given to the right patient with the help of mobile apps RFID reader and label. Analysis of medical record data is driving the transformation from hardcopy based medical record data to the digital medical record data, access of digital historical health condition of the patients and reporting the progress of patient health in digital as an application feature is needed to make sure the patient safety in using of the drug, by supporting mobile apps. Analysis of drugs attribute to transform digital of drug ingredients, so the application should have an ability to scan and show information about medicines that will give to the patient and compare the data with the medical record data, to make sure the allergic and the drug therapy has a negative side effect to the patient or not, with the support of mobile apps, RFID reader and label. Analysis of drug consumption transform the drugs side effect monitoring by a digital system, and the application needs to provide real-time tracking and healing progress by updating the patient condition; the patient should give exact condition about their health progress, and also monitoring heartbeat, blood pressure and the body temperature by using mobile apps. Analysis of inventory data transforms drugs labelling and control by IoT system. The application provides the purchase requisition system, input drugs information, drugs labelling, and distribution monitoring by scanning the label of the drug to make sure the drugs supply has corrected information and quantity. It is more accessible also for the monitoring of medicines used. Mobile apps, RFID reader and label, is needed to support this system.

3.3 Business architecture reference model

The reference model that the author makes represents how information technology should be. The author adds some technology to help healthcare professionals easier to detect and control drug use. RFID label will stick on a medicine or medicine container and has information about the drugs. The RFID reader will read the RFID reader data and show the information on a tablet or mobile. Mobile apps will be a platform to manage the data. It will take time to input the data at the beginning, but in the end, it will be easier later on. The technology also brings some new hope to reduce or mitigate a risk in using drugs. The reference architecture model explains in figure 4 shows the actor and business service on a business layer. Application component and infrastructure service on an application layer. Infrastructure on a technology layer.

4 CONCLUSION

Reference enterprise architecture model based on TOGAF, define the process with the IoT system. The IoT system was put in an area that has a gap. This reference enterprise architecture model as an ideal model, make to help medical professionals get insight to reduce risk and minimize the gap of drugs distribution. RFID technology is a new hope to reduce and mitigate risk in the supply of drugs in healthcare facilities. Hopefully, in the future, no more wrong drugs dispense cause of the human error and make negative side effects to the patient

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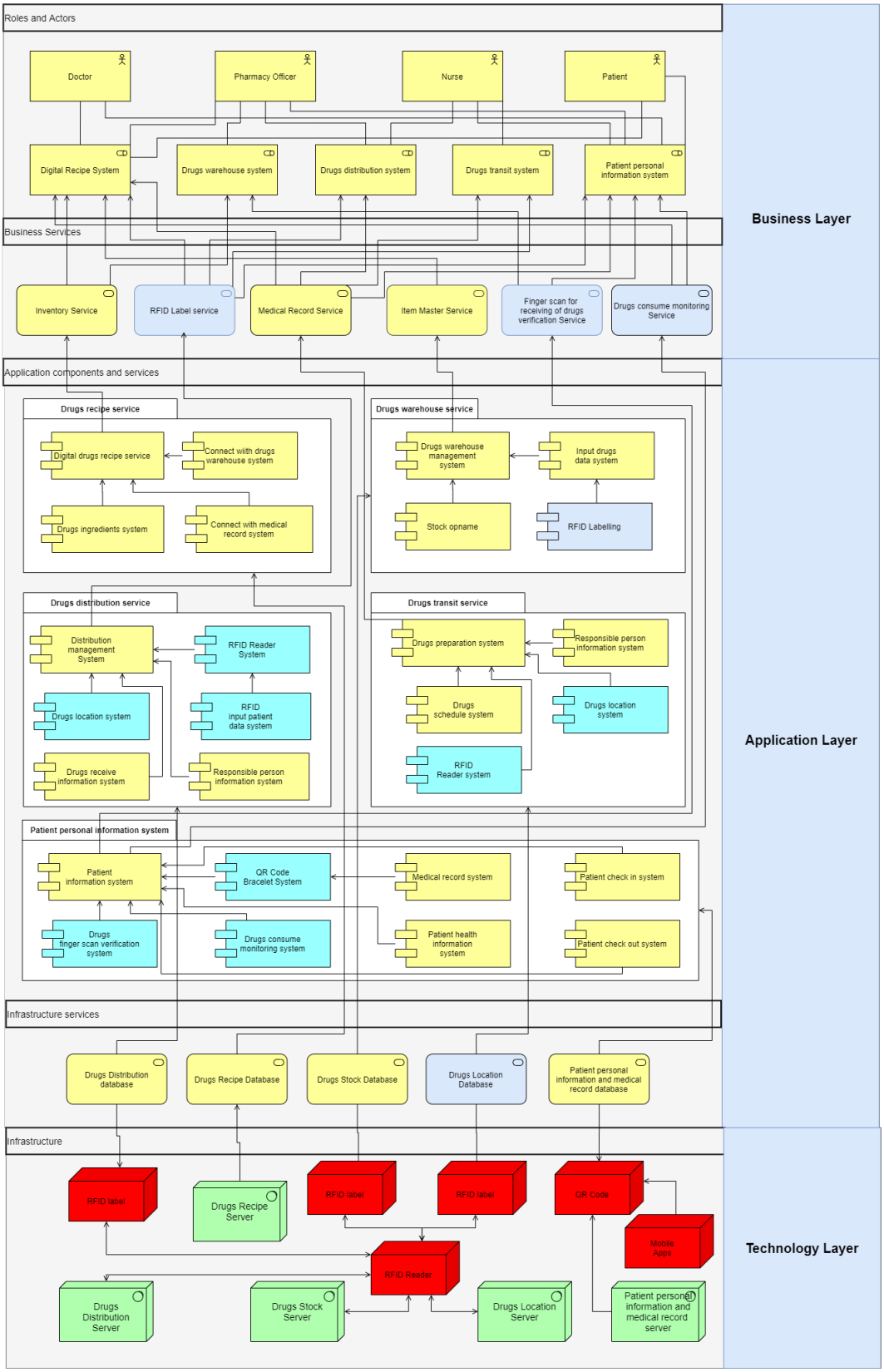

Figure 4: IoT Based Enterprise Architecture Model for Monitoring Safety of Drugs Supply to The Patient at Hospital

REFERENCES

[1] S. Ali Kusnadi, Manajemen Obat di Rumah Sakit. 2015.

[2] L. Tampubolon, "Analisis Penerapan Prinsip Keselamatan Pasien Dalam Pemberian Obat Terhadap Terjadinya Medication Error di Rawat Inap Rumah Sakit X Tahun 2018," vol. 4, p. 11, 2018.

[3] M. R. Cohen, J. L. Smetzer, J. E. Westphal, S. C. Comden, and D. M. Horn, "Risk models to improve safety of dispensing high-alert medications in community pharmacies," Journal of the American Pharmacists Association, vol. 52, no. 5, pp. 584–602, 2012, doi: https://doi.org/10.1331/JAPhA.2012.10145.

[4] A. Craswell *et al.*, "The impact of automated medicine dispensing units on nursing workflow: A cross-sectional study," International Journal of Nursing Studies, vol. 111, p. 103773, Nov. 2020, doi: 10.1016/j.ijnurstu.2020.103773.

[5] A. J. Jara, A. F. Alcolea, M. Zamora-Izquierdo, A. Skarmeta, and M. Alsaedy, "Drugs interaction checker based on IoT," Jan. 2011, pp. 1–8. doi: 10.1109/IOT.2010.5678458.

[6] A. Agrawal, "Medication errors: prevention using information technology systems," British Journal of Clinical Pharmacology, vol. 67, no. 6, pp. 681–686, Jun. 2009, doi: 10.1111/j.1365-2125.2009.03427.x.

[7] C. J. P. Siregar, "Farmasi Rumah Sakit Teori Dan Penerapan," 2003.

[8] Isaca, The Risk IT Practitioner Guide. ISACA, 2009. [Online]. Available: https://books.google.co.id/books?id=L1CVGVxHGpcC

[9] I. Mahendra, "Kondisi Pasien RS Tenriawaru Parah, Diduga Perawat Salah Kasih Obat," Global Terkini, Jun. 08, 2020. https://www.globalterkini.com/2020/06/kondisi-pasien-rs-tenriawaru-parah-diduga-perawat-salah-kasih-obat.html (accessed Sep. 28, 2021).

[10] "Rumah Sakit Salah Memberi Obat Pasien." https://www.kompas.tv/article/126718/rumah-sakit-salah-memberi-obat-pasien (accessed Sep. 28, 2021).

[11] J. Dul and T. Hak, Case study methodology in business research. Boston, MA: Elsevier, 2007.

[12] S. Teegavarapu, J. Summers, and G. Mocko, "Case Study Method for Design Research: A Justification," Proceedings of the ASME Design Engineering Technical Conference, vol. 4, Jan. 2008, doi: 10.1115/DETC2008-49980.

[13] M. Taleb and O. Cherkaoui, "Pattern-Oriented Approach for Enterprise Architecture: TOGAF Framework," Journal of Software Engineering and Applications, vol. 05, Jan. 2012, doi: 10.4236/jsea.2012.51008.

A Case Study of IIoT Application in Process Manufacturing

Management Information Systems in Palm Oil Refinery

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ABSTRACT

Industrial Internet of Things (IIoT) is providing technology integration of Information Technology (IT) and Operation Technology (OT). While OT is related to operational in shop floor production, IT has become a backbone in corporate management strategic decision making. Both technology are dependent to reliable data, comprehensive analysis from it, and utmost distribution network to related parties. In Industrial Revolution journey, Programmable Logic Controller invention has been part of important part of OT and trigger to the Third Industrial Revolution. The elaboration in Computer Integrated Manufacturing concept has been strengthened by technology providers to deliver reliable solution in manufacturing process. However, these data remain to reside in isolated environment of Industrial Control System. While focusing in process operational automation system, integrated information management become issue in this case study. Manual log sheet in Margarine and Shortening production of Palm Oil Refinery is backbone for process parameter visibility and downside in issues to reliability, distribution, and further analysis. By optimizing available technology in the Fourth Industrial Revolution, this vertical integration from shop floor production to corporate management could be delivered with IIoT-based Information Systems. Methodology from Industrial Internet Consortium (IIC) publication in Industrial Internet Reference Architecture (IIRA) which connected to existing automation system is providing real-time data with historical trending. The velocity and volume of these data has shaped Big Data and presented Management Information System in IT network. This reliable data provide traceability to parameter process in production facilities.

CCS CONCEPTS

• **Information systems**; • **Data management systems**; • **Information integration**; • **Mediators and data integration**;

KEYWORDS

IIoT, IT and OT Convergence, Industrial Revolution, Industrial Control System, Information Systems, Palm Oil

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1 INTRODUCTION

Industrial Control System is highly influenced with Computer Integrated Manufacturing (CIM) concept. Since Programmable Logic Controller (PLC) invention in late 1969 by Dick Morley, CIM has paving it with computer technology to control entire production process. The concept has been approached by Purdue model which later being standardized in ISA-95. It has become guidance in industry implementation to integrate shop floor production (where process is happened through equipment) to corporate management (which considered as external influences) as shown in Figure 1. Integrated information management and automation system is shaping this hierarchy in vertical arrangement.

Automation system is playing important role to supervise process equipment in production facilities and program it with specific application function. This hierarchy is stepped up from instrumentation, then sensor readings is delivered to PLC, where logic is embedded, and later to be translated in Supervisory Control and Data Acquisition (SCADA). From computer, operator will able to oversee factory as shown in example of Figure 2. This display is representing Piping & Instrumentation Diagram (P&ID) and ongoing process with process data. In continuation to this data set, operator could run automatic function and production will be controlled in less human intervention. Data Acquisition is reversed in Control function arrangement from SCADA, to PLC, and later instrumentation (such as actuators). Technology development in the automation system is flourished with objectives to ensure plant reliability and determinism. Industrial standard takes form in robust hardware to withstand harsh environment. Software application is fulfilled with programming flexibility and library object in specific process industry. Industrial Control Network also developed in proprietary standard or specific preference in fieldbus technology to communicate between instrumentation, PLC, and SCADA.

The determinism in Industrial Control System has a downside in data integration. Integrated information management is facing challenges in its connectivity and collection. Since network communication is developed by technology provider or consortium, data flow found its challenges for interconnection. As this function is less critical in operational, plant's users remain focus in assurance of

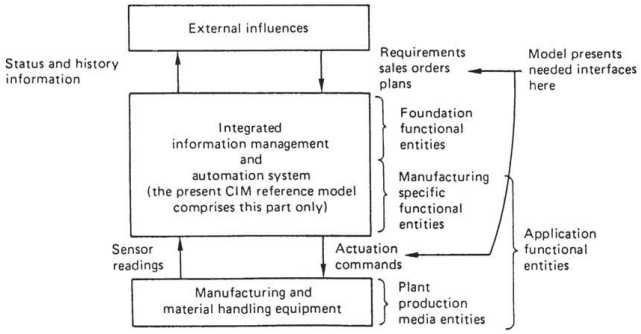

Figure 1: CIM Reference Architecture in Purdue Model [10]

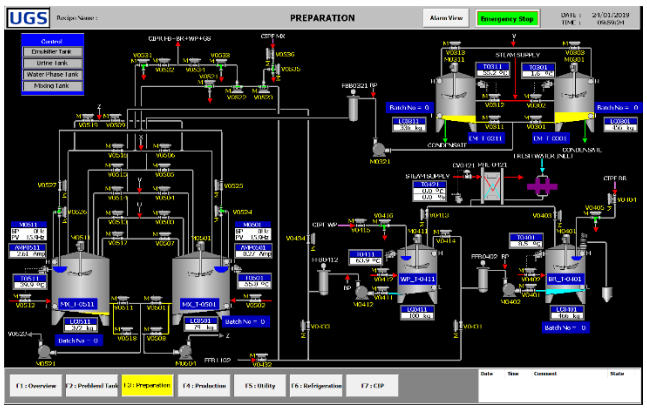

Figure 2: Sample of SCADA display in process manufacturing

automation system and tied to specific brand with data recording in manual-based. Information Technology (IT) on the other hand have limitation to interpret communication protocol in this Operational Technology (OT) side. This situation is part of digital transformation in industry through Industrial Internet. By leveraging internet technology in industry, concept of interconnection is formed in more flat structure. Multitude of industrial devices connected that result in systems to monitor, collect, exchange, analyze, and deliver valuable new insights to management of corporation. This word of Industrial Internet was coined by General Electric in 2012 and also known as Industrial Internet of Things (IIoT). [5]

The global competition and maturity of IT and OT level has started advanced manufacturing or smart factories. Germany as one of global leader in manufacturing equipment sector tap the potential from Internet of Things and Services technology novelty. This technology is ushering the Fourth Industrial Revolution (Industry 4.0). Concept of Cyber-Physical System will connect machinery, warehouse system, and production facilities in global business network. The journey initiatives is prepared by working group and launched by Germany in Hanover Messe 2013 as Industrie 4.0. The features of horizontal and vertical integration of manufacturing systems and end-to-end integration of engineering is part of characteristics in this industrial revolution [3]. Spreading to another nation scale, Indonesia also adopted Industry 4.0 era by launching roadmap Making Indonesia 4.0 in 2018. This roadmap is prioritizing to five industry sectors: food and beverages, textiles, automotive, electronic, and chemical. High impact and feasibility are part of this industry selection with Palm Oil Industry is incorporated into Food and Beverages sector. In 2021, USDA stated Indonesia as largest CPO producer with 59% of contribution to world supply [8].

In this case study, authors deliver an application design of Management Information System to integrate data from Industrial Control System in four production facilities of Palm Oil Refinery. The integration is delivered with IIoT platform to support management challenge in data collection from site to different location of head office. The collection time need to be better than previous manual recapitulation of daily based or hourly manual record. Reason of this data aggregation is to provide analysis by competent division in Head Office if any issue regarding quality is occurred. Longer lead time will jeopardize company reputation from customer complaints. By having data traceability, company will able to have transparency in parameter process compliance and data integrity assurance for all stakeholder. Also, in real-time data collection, further prevention to quality out of specification will be beneficial for operational.

2 METHODOLOGY

2.1 Production Facilities Survey

The survey is conducted in location of West Java province, from period 2019-2021 with monthly event. In location, there are five major production areas:

- Crude Palm Oil (CPO) refining to Refined Bleached Deodorized Palm Oil (RBDPO)
- RBDPO fractionating to Stearin and Olein
- Cocoa Butter Substitute (CBS)
- Margarine and Shortening (Marsho)
- Cooking Oil Filling

In Marsho production area, there are four production unit running with ongoing commission of another three projects. Products of margarine and shortening is processed from mixing of several oil types [6]. This preparation will mix those types of oils in mixing tank with specific formulation and then being emulsified. Product output is having shock cooling and scrapped in cooling-working machine. Temperature arrangement from ammonia compressor will determine result of quality. All critical parameters in Pre-blend section, Preparation section, and Production section is managed by automation system in control room as described in Figure 3. Automation system in Marsho production area is consisting of field device network to sense and actuate process, communicate with PLC, and having SCADA on top of this integration for overseeing whole production process. Field instruments are having variety of combination communication protocol, with Profibus protocol as major backbone. Industrial Ethernet is being used to connect data and command from PLC to SCADA [7].

From ongoing discussion and observation, production facility information systems is recorded in daily log sheet. On log sheet, operator will record every process parameters (tags) hourly in paper based. These paper collection will be recapitulated in spreadsheet for further information distribution across corporate network and business function through e-mail or SAP. The whole process last 1-2 days from West Java Site to Jakarta Head Office. The product will be inspected by Quality Control team to ensure its compliance before

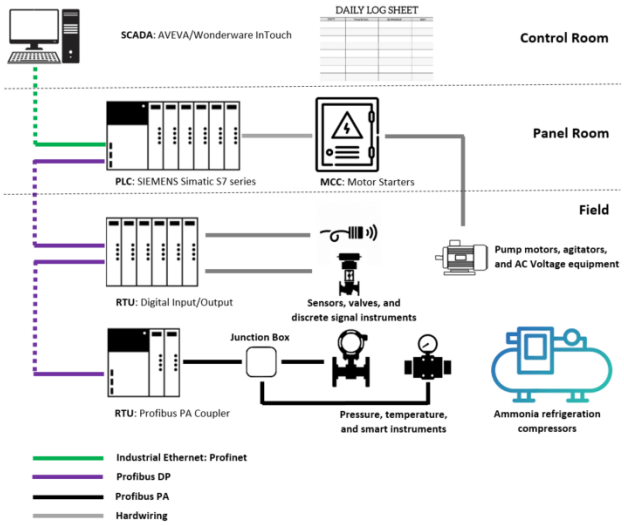

Figure 3: Typical System Architecture of in surveyed facilities

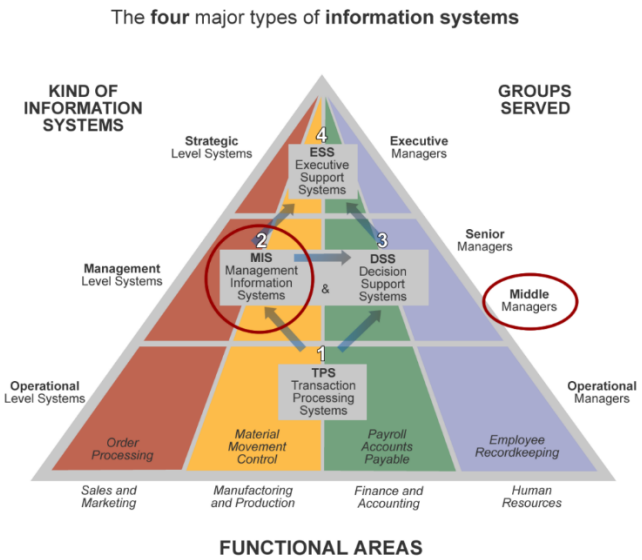

Figure 4: Major Type of Information Systems [6]

dispatch to consumer. However, product stability is one of available challenges that caused rejection or complaint in customer arrival point. From customer complaint event, company need to provide swift response for it in 48 hours. In time limitation to investigate across value chain, parameter process of production facilities is major highlight for this quality deterioration. However, as data recapitulation will take time more than expected response, most cases will end to product replacement and if no specific finding in manual log sheet, then product formulation is also evaluated to ensure its stability.

The requirement to provide accepted platform across Production, Quality, and R&D team need to be bridged by management so that focus to customer satisfaction could be fulfilled. This opportunity is become objective during case study to deliver Management Information System. In further elaboration, human intervention is reduced that data recording need to be live taken from instrumentation reading. This selected data will be critical parameters in production facilities. Upon agreement in critical parameters, related parties will use that data and provide expected analytics method in each department. There are options to connect data from instrumentation, PLC, or SCADA layers. In decision, data is taken from SCADA to consideration of low disturbance in ongoing process and potential of scalability. From inspection, there are 1,934 active tags in Marsho 1 production facility, 1,278 active tags in Marsho 2 production facility, 1,074 active tags in Marsho 3 production facility, and 8,370 active tags in Marsho 4 production facility. In implementation viewpoint, IIoT present potential connectivity in Industrial Control System to build Management Information System.

2.2 Literature Review

Information Systems has been improving business processes in organization. From manual action, system has transformed and enhanced it in information flow across company. This is enabled with computer-based information systems that collect, process, store, and distribute information to support decision making and control in an organization. As part of major business functions, manufacturing and production need to be aligned with business objectives. This is crafted from integration with Transaction Processing Systems which being used in operational. Management Information Systems is being used by management level systems to deliver information into Decision Support Systems and Executive Support Systems as shown in Figure 4. The technology novelty is part of instrument in achieving it and creating value for company. [1, 2]

Since IoT development in global acceptance, the growth has reached significant amount and prediction to have a booming demand in years ahead. The number of IoT global connections grew by 8% to 12.3 billion active endpoints despite of ongoing COVID-19 pandemic [4]. Along with that, different organizations and consortium has been crowded in this IoT landscape. One of them is Industrial Internet Consortium (IIC) founded in March 2014. Their focus mainly to create use cases, reference architectures, frameworks, and test beds for industries. One of their publication in IIoT approach is published into Volume G1: Reference Architecture document. The publication deliver Industrial Internet Reference Architecture (IIRA) with different layer of viewpoint. Implementation Viewpoint is concerned with technical representation of an IIoT system. This is represented in three-tier system architecture as shown in Figure 5. The three-tier is started from Edge-tier to collect data from edge nodes and specific to this case study is SCADA and machine controller. From Edge-tier, Gateway-Mediated Edge Connectivity will flow data to Platform-tier. Message Queuing Telemetry Transport (MQTT) broker will be used in this case study as Edge Gateway to Ignition platform. Finally Enterprise-tier will harvest beneficial of these data in form of Management Information

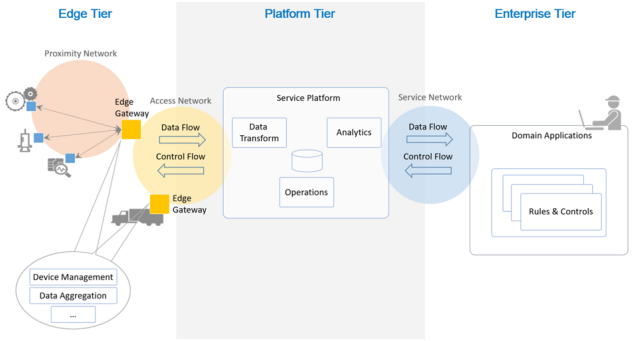

Figure 5: The Three-tier IIoT System Architecture

System to decision support systems and provide interfaces to end users including operation specialists. [9, 10]

2.3 Management Information System Architecture

In conceptual of IIRA, design is build based on existing Industrial Control System. As multiple production unit need to be integrated, Edge Gateway is placed as proximity network to collect data from SCADA and machine controller. From initial active tags, parameter is being selected to provide critical process required. Two major parameters is expected from this platform: quality management system and asset maintenance system. Quality analysis will be conducted based on production actual parameter in boundary diagram to ensure its compliance to recipe used. While for asset, running hour will be parameter to advise scheduled maintenance to be conducted. Machine controller is being used to retrieve alarm and ammonia compressors parameter. All parameters will available to represent every production unit real-time condition, fulfilling functional and usage viewpoint. Every unit will consist of: one SCADA system and one ammonia compressors controller. It represents production unit in West Java site. From each Edge Gateway, MQTT connection is established to Broker. This broker is stationed in local site as on premise server and named as MQTT Server. It will act as message-oriented middleware solutions between publisher in Edge Nodes and Ignition Server as subscriber. Subscribed data will be aggregated and designed in visualization form for client view in Enterprise-Tier. All access to from Enterprise-Tier will be available from Ignition client application based on Java as business viewpoint in application.

2.4 Project Implementation

The application is implemented in waterfall methodology from Marsho 1, Marsho 2, Marsho 3, and Marsho 4 with three production areas in ongoing commission during paper publication in 2022. This to ensure connection from each control system is properly mapped and connected to Edge Gateway. From available communication option, OPC UA is being used for SCADA connection and Modbus TCP for machine controller as shown in Figure 6. The MQTT connection is established from Edge Gateway configuration. MQTT usage is adopted as global industry standards in the Industrial IoT as published by IEC. Physical cable laying then connect Edge Gateway

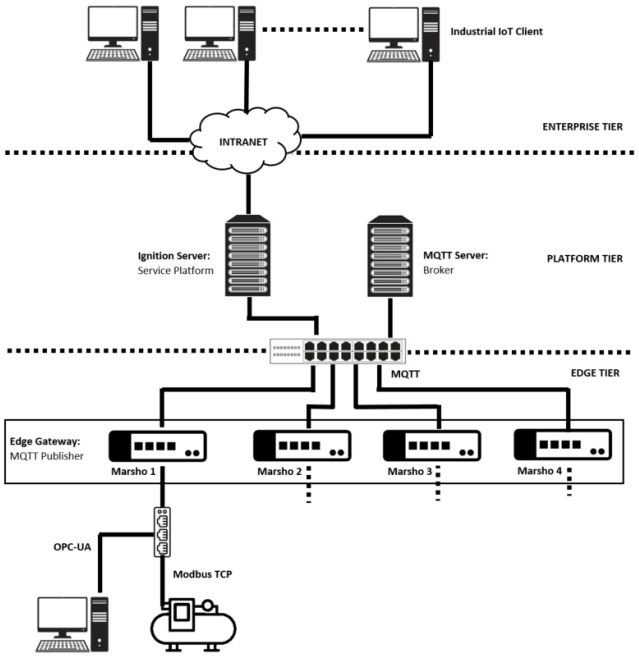

Figure 6: IIoT System Architecture

to MQTT Server, a broker which decouple publisher (Edge Gateway) and subscriber (Ignition Server). Data flow from Edge Nodes will be part of publishing data to Ignition Server. In Ignition Server, reporting and dashboard function is formed for MIS clients. This connectivity will use IT network infrastructure, while hardware are using on premise servers which located in control room and managed IT server room.

After hardware, software, and data integration, discussion is conducted between Production, Quality, and Engineering team to form expected information to be available in Management level and aligned to business requirements.

3 RESULTS

From this integration, minor modification is required to install OPC UA in SCADA server. From there, communication between data tags to Edge Gateway is established. Also, in different type of machine controller option communication protocol is standardized in Modbus TCP. The Modbus address mapping is used to understand address representation in process parameters. Total parameter in IIoT system is 12,643 tags which coming from seven production units with MQTT transmission. Phase 1 has been stable monitored and phase 2 for another three production units is under commission. From total tags, 8,658 is representing SCADA and machine controller tags while remain is used for MQTT distributor and engine. The network and infrastructure in this application is segregated to three layers: OT domain from SCADA server connection to PLC and instrumentation, IIoT where IT and OT convergence is happening from SCADA server to MQTT server and Ignition Server, and last IT domain from Ignition Server connection to multiple clients access.

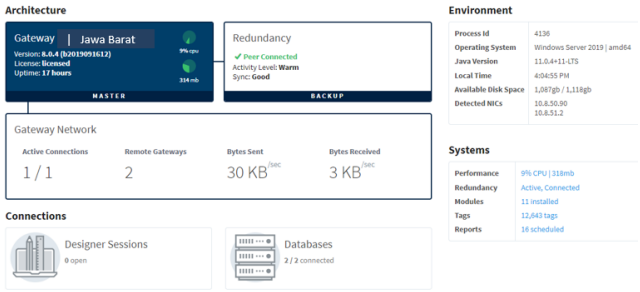

Figure 7: Overview of System Performance

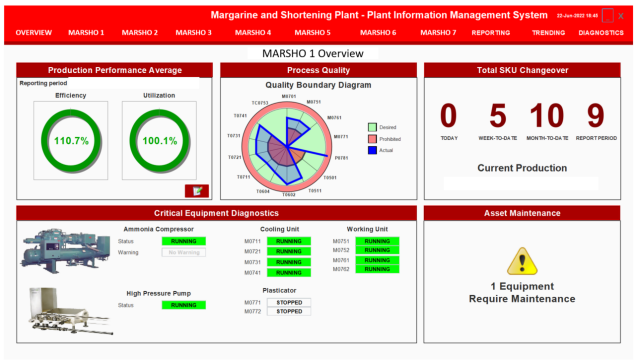

Figure 8: Visualization of Management Information System

In alignment to CIM concept, integration to corporate management level is delivered in Management Information System where visualization is being used by respected parties. Visualization is formed in grid view that reflect specific subject in the system: Production Performance, Process Quality, SKU Changeover, Critical Equipment Diagnostics, and Asset Maintenance. Data traceability is available in form of Report (fix type to replace manual log sheet and custom to have specific parameter process for analysis purpose) and Trending to view graphical all process parameters in two years period storage. All customization in tags selection are being provided to build correlation in the production process.

From available information, Production team is optimizing data in Production Performance and SKU Changeover to ensure their efficiency and utilization. By having these data, they could align production planning in short to provide available production line. Also, best configuration with available material for product planning. Process Quality with details of time-series database is providing compliance of ongoing process parameter to recipe of product. By having Quality Boundary Diagram, actual critical parameter is compared between Desired (in range) to Prohibited (out of range). Asset Maintenance function is reflected in Critical Equipment Diagnostics and forming maintenance schedule. This apply from data connectivity in machine controller for Ammonia Compressors and running hour of rotating equipment (electrical motor starter). If any exceeding working hour, notification will appear to remind users in maintenance schedule.

4 ANALYSIS AND DISCUSSION

System performance still have extensive room for further data integration. The lightweight data connectivity from IIoT based on MQTT also provide opportunity for optimization in cloud-based environment adding to on premise server investment. This is shown from platform overview as shown in Figure 7 with 9% of CPU usage. Scalability is prepared in sequence stage to cover another extensive production areas in site location. Hardware redundancy also implemented in this case study to ensure high availability system in this Management Information Systems

On the other hand, Management Information System application providing comprehensive quality assurance and asset maintenance in the platform for middle management supervisory. Parameter process as shown in Figure 8 could be monitored in shorter time transaction, while for specific analysis could optimize longer data in historical. The data transparency and ease of access provide traceability in product delivered to end customer and technology platform is considered novelty in the industry revolution.

Cybersecurity remains in further topic of this integration. Network and infrastructure convergence between multiple layers will open potential vulnerabilities in whole system from corporate to ship floor production. Adding to another potential topic is Artificial Intelligence. How data aggregation and visualization could be used as set of training data for machine learning and contribute to asset maintenance management.

5 CONCLUSION

The case study present implementation of IIoT application in process industry. This is displayed by Management Information System in Palm Oil Refinery as research object which is based on IIoT. From available seven production units, this MIS connect 12,643 tags from MQTT transmission. Connectivity technology offered by Industrial Internet play an important role in this industry because of industry location nature. With its geographical scattered location across the island, this novelty technology unleashed potential to have a resilient and sustainability data-driven decision management. Management Information System availability provide not only data availability and transparency, but also further data mining could deliver value in operational, management, or strategic level. At last, this representation not only related to specific industry type, but also its contribution as one of major high impact to nation scale. Following Indonesia roadmap, it is expected adoption of Industry 4.0 able to revitalize manufacturing sector and leverage nation growth.

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REFERENCES

[1] David T Bourgeois. Information Systems for Business and Beyond. 167.
[2] Miguel Pinto Caldas. 2003. Management information systems: managing the digital firm. *Rev. adm. contemp.* 7, 1 (March 2003), 223–223. DOI:https://doi.org/10.1590/S1415-65552003000100014
[3] Communication Promoters Group of the Industry-Science Research Alliance and acatech - National Academy of Science and Engineering. 2013. Recommendations for implementing the strategic initiative INDUSTRIE 4.0.

[4] Mohammad Hasan. State of IoT 2022: Number of connected IoT devices growing 18% to 14.4 billion globally. Retrieved from https://iot-analytics.com/number-connected-iot-devices/
[5] Collin Parris. What is the Industrial Internet of Things (IIoT)? Retrieved from https://www.ge.com/digital/blog/what-industrial-internet-things-iiot
[6] Pusat Data dan Informasi. 2017. Gambaran Sekilas Industri Minyak Kelapa Sawit.
[7] Martin Rostan. 2014. Industrial Ethernet Technologies.
[8] United States Department of Agriculture. 2022. Palm Oil 2021 World Production. (April 2022). Retrieved from https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=4243000&sel_year=2021&rankby=Production
[9] Theodore J. Williams. 1989. A Reference Model for Computer Integrated Manufacturing (CIM).
[10] T.J. Williams. 1990. A Reference Model for Computer Integrated Manufacturing from the Viewpoint of Industrial Automation. *IFAC Proceedings Volumes* 23, 8 (August 1990), 281–291. DOI:https://doi.org/10.1016/S1474-6670(17)51748-6

Preliminary ECG Cloud-based Telecardiology System for Rural Areas

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ABSTRACT

According to the Ministry of Health of Republic Indonesia, cardiovascular disease the number of sufferers continues to increase every and ranks the highest cause of death in Indonesia. The most common CVD manifestation is atrial fibrillation. The CVD prevalence in rural areas of Indonesia is 1.3% and only one-third of CVD patients received preventive treatment. The low number of patients receiving preventive treatment is due to a shortage of active cardiologists and an unoptimized health care facility integration system in Indonesia. Therefore, a virtual access system equipped with a computer-aided diagnosis that connects a public health center in a rural area with cardiologists in a district hospital for better health care service performance. In this research, the virtual access system was developed by using Amazon Web Services along with ESP32 and micro-SD for simulating the ECG data transmission. The developed system can be accessed publicly and able to do cloud computation to detect atrial fibrillation. Furthermore, the developed system data transmission with the buffer method showed a result of 0% data loss in 1 minute, 5 minutes, 60 hours; and 0.0014% of extra data for 24 hours of transmission. Thus, the developed system has a high possibility for Holter monitoring and its implementation is not limited to ECG signal data transmission.

CCS CONCEPTS

• **Hardware** → Communication hardware, interfaces and storage; • **Computer systems organization** → Architectures; Distributed architectures; Cloud computing.

KEYWORDS

ECG, Telecardiology, Cardiac Arrhythmia, Cloud Computing, Data Transmission

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1 INTRODUCTION

Indonesian Government Regulation, Peraturan Pemerintah 47/2016, divides Indonesian Health Care facilities into 3 classes [12] the primary health care facility such as "Puskemas" (Public Health Center or PHC), provides basic health care; the secondary health care facility provides specialized health care, and the tertiary health care facility provides subspecialized health care. "Sistem Rujukan" or Reference System provides for the integration and connectivity among the three facilities [10]; however, the Ministry of National Development Planning of the Republic of Indonesia reports that this system has not been fully optimized. Inadequate infrastructures, including transportation and funding; increasing inaccessibility, owing to population sprawl; and poor program management are several key contributors to system failure [10]. As a result, providing healthcare services such as preventive care for rural areas residents in Indonesia is still quite challenging.

According to the Ministry of the Health Republic of Indonesia, cardiovascular disease (CVD) is one of the diseases that continues to increase every year and ranks the highest cause of death in Indonesia, especially at productive ages [2]. In addition, it is also mentioned that the prevalence of CVD in rural residents is 1.3%. However, only one-third of moderate to high-risk CVD patients received preventive treatment [3]. Therefore, it is crucial to comprehend the factors that trigger CVD manifestation. Hypertension and DM are prevalent comorbidities that increase the risk of cardiovascular disease (CVD) and promote its manifestation [9]. Hence, CVD along with hypertension, are the leading cause of morbidity and mortality in diabetes patients [4]. Screening for CVD is important to prevent events such as heart failure, strokes, and asymptotic deaths [1]. Detecting cardiac arrhythmia is one of the methods to monitor CVD manifestations. Preventative care in the pre-stages of CVD is also limited by the shortage of active cardiologists in Indonesia, while the number of CVD patients and those predisposed to move along that path might continue to grow [8].

Within the possible paths listed above that move toward CVD where prevention can best be intensified and contribute to decreasing mortality, a promising entry point can be found in the work of Rosiek, whose claim that early transmission of Electrocardiogram (ECG) measurements is the solution to suppress the death numbers caused by cardiac arrest [5].

In this paper, a cloud-connected system at a rural PHC will be developed. A clinical data network system will be used to transfer

ECG measurements to a higher health care facility so that can be reviewed virtually. Consequently, a cardiologist can provide a virtual diagnosis and the patient would only need to visit the primary care setting for screening. As a result, this system of telemedicine can eliminate the need for creating the funding and transportation infrastructure it presently lacks and offset the insufficient number of cardiologists by removing the boundaries and geographical limitations of their practice, specifically for the preventive treatment of CVD. In addition, research work conducted by Setiawan regarding a cloud computing algorithm to detect arrhythmia was used as a reference point for this paper [7]. Other applications of this system would be possible but are not the subject of this work.

2 METHODS

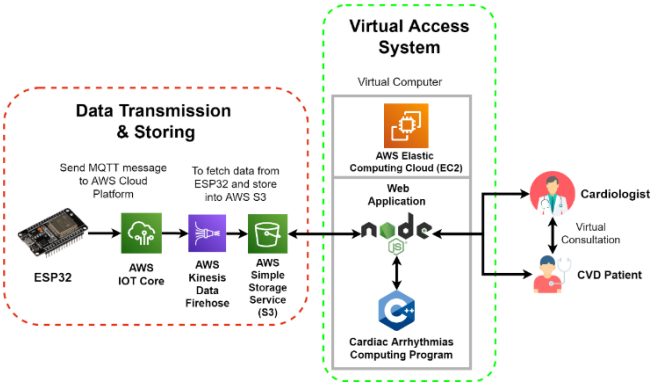

Figure 1: System architecture of ECG telecardiology using Amazon Web Service

Figure 1 illustrates the final architecture system design using Amazon Web Service (AWS). AWS was chosen as a cloud service due to its services complied with the U.S. Health Insurance Portability and Accountability Act of 1996 (HIPAA). This is important to ensure data security within the AWS environment.

The developed system architecture consists of two main parts, data transmission & storing architecture marked by the red dotted line and the virtual access system, inside the green dotted line. Both parts will be discussed further in the following subsections.

2.1 Data Transmission and Storing

To simulate the ECG transmission data from rural PHC, the datasets of the MIT-BIH Atrial Fibrillation Database were stored in a micro-SD card and connected to the ESP32. The data reading and parsing process were run at a 5 ms delay with a sampling rate of 200 samples per second. Then, the ESP32 was connected to an electrical socket with the help of a USB power adapter via a micro-USB cable. The setup was placed in a rural PHC and the setup presented in Figure 2.

Afterwards, the ESP32 publishes messages containing the parsed data to AWS IoT Core in a cloud environment using two methods:

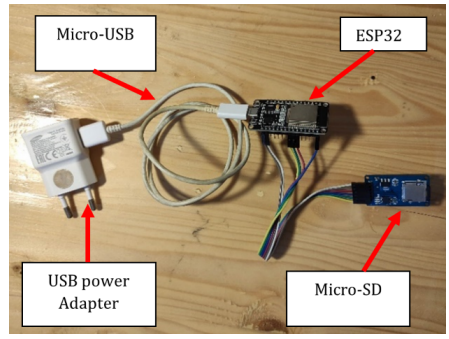

Figure 2: ECG data transmitter device setup

- Direct Method:

The data parsing process from SD-micro card to JSON objects and serialized into a JSON format document were done procedurally. In other words, the data is directly sent to the cloud system and the JSON serialization can be seen as follows.

```
{``No'': ``INDEX_1'', ``mV'': ``DATA_1''},
{``No'': ``INDEX_2'', ``mV'': ``DATA_2''},
                {...},
{``No'': ``INDEX_N'', ``mV'': ``DATA_N''}
```

- Buffer Method

This method uses an array to temporarily store the parsed data before serializing it into a JSON format document. The array was set to store 25 data. As a result, the data is sent as a batch. Underneath is the serialization of JSON with the Buffer Method.

```
[{``No'': [INDEX_1,...,INDEX_25], ``mV'': [DATA_1, ...,DATA_25]},
{``No'': [INDEX_26,...,INDEX_50], ``mV'': [DATA_26,...,DATA_50]},
                {...},
{``No'': [INDEX_N,...,INDEX_N+25], ``mV'': [DATA_N,...,DATA_N+25]}]
```

Then, the recorded ECG signal data is directed using a delivery system called AWS Kinesis Data Firehose to static content storage, AWS S3 in a bucket. To retrieve the stored ECG signal data, the web application back-end queries the AWS S3 bucket object list and presents it to the GUI. As a result, users can select the desired ECG signal data and download it in a JSON format. The data transmission and storing flow diagram can be seen in Figure 3.

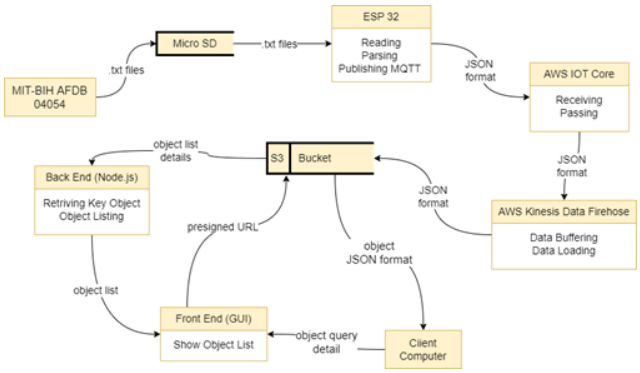

Figure 3: Data transmission and storing flow diagram

2.2 Virtual Access System

On the virtual access system, the AWS EC2 instance or virtual private server hosts the previously developed web application utilizing Node JS as the runtime environment [7]. This virtual access system can be accessed at http://18.141.188.48:3001/. In addition, a compiled C++ language program is integrated into the web application to extract the ECG signal features. The web application user interface is shown in Figure 4.

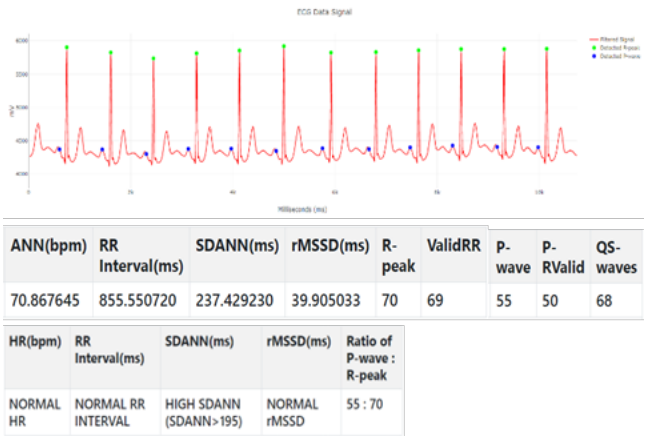

Figure 4: Web application user interface

Before beginning the cloud computation process, the previously downloaded file is converted from JSON format to a .csv file. Some JSON format files contain a nested data array which must be converted into a basic array. A python program stacked the nested array into two columns, the first column is the header, and the second column contained the index and data. Next, the filtering process was proceeded by searching for headers with the same name and then combine into two arrays, the first array contained indexes, and the other contained the recorded data. Next, the header of each array was removed and both arrays were merged into a single array and finally converted into a .csv file. The converter program flow is presented in Figure 5.

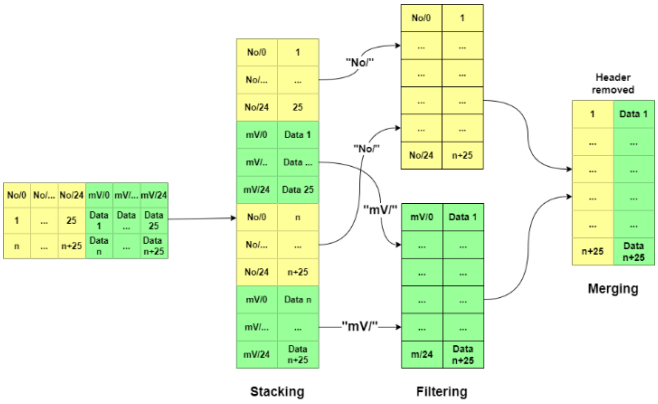

Figure 5: Nested array to basic array conversion flow

Next, the previously converted ECG signal data is uploaded back to the web application and directly computed by the compiled ECG signal computing program. After the computation, the result files are not only stored in the EC2 instance but are also stored back in another AWS S3 bucket. To show the computation result, the computed files inside the instance are called to the application and displayed on the web application. As a result, the users such as cardiologists or patients can examine the computed ECG signal data. The above data flow is illustrated in Figure 6.

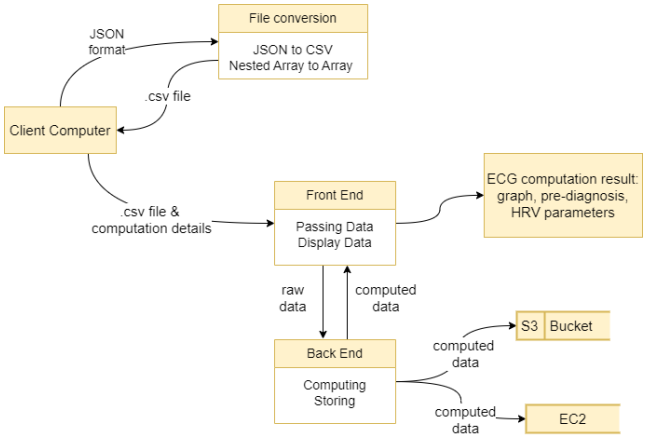

Figure 6: Virtual system and cloud computation flow diagram

3 RESULT & DISCUSSIONS

In this research, an ECG telecardiology architecture system for the rural area has been successfully developed by using AWS services. The ESP32 along with the micro-SD acted as the data transmitter, AWS IoT core as the data receiver, Kinesis Data Firehose as data delivery service, AWS S3 as the cloud storage, and the EC2 instance as the virtual server. This system was able to be accessed publicly because of the EC2 instance. This helps either medical workers or patients to access virtual access from anywhere and anytime which fulfills the first objective of this research.

3.1 Comparison Studies

In a comparison of the system, research in 2018 conducted by Zilani et al., a patient health monitoring with an IoT approach was developed [11]. In this research, the developed system was able to measure patient vital signs such as ECG signal, oxygen saturation level, and respiratory airflow. AWS IoT Core was utilized to transmit all the information to the system. However, the web user interface was available on a local or private server and no explanation regarding data storage in this research.

In another more recent research, a real-time remote ECG monitoring system was developed along with AWS S3 [6]. This system uses Bluetooth low energy (BLE) to transmit the data from the ECG sensor to a mobile. Subsequently, the data was conveyed to the S3 bucket via a mobile gateway with a 4G connection. In addition, the recorded data was only able to be observed via a mobile app.

Table 1: Direct method data loss

Duration (minute)	Attempt	Data Received (n)	Data Loss (n)	Avg. data Loss (%)
1	1	7601	4399	36.38
	2	7701	4299	
	3	7601	4399	
5	1	36872	23128	38.8
	2	36890	23110	
	3	36840	23610	

Table 2: Buffer method data loss

Duration (minute)	Attempt	Data Received in Thousands (n)	Data Loss (n)	Avg. data Loss (%)
1	1	12	0	0
	2	12	0	
	3	12	0	
5	1	60	0	0
	2	60	0	
	3	60	0	
60	1	720	0	0
	2	720	0	
	3	720	0	

3.2 Data Transmission Reliability Test

The data transmission reliability test was conducted to check the data integrity. The experiment was performed in Puskesmas Kintamani VI, a rural PHC in Bangli, Bali, Indonesia. The device was connected to the PHC WiFi connection with an average ping of 31 ms to the AWS IoT Core endpoint.

The direct method was able to transmit the data right after the parsing and serializing process. However, these burdens the AWS cloud system in receiving lots of messages in a short time i.e., data message spamming. As a result, the data loss was around 36% - 39% during the transmission.

In contrast, the buffer method has successfully managed the data integrity for data transmission with a duration of 1 minute, 5 minutes, and 1 hour with 0% data loss which satisfies the second objective of this research. For the 24-hours data transmission, there was 0.0014% of unwanted extra data stored in the S3 bucket. It might occur due to the AWS server restarting or data delay at 01:00-01:20 or human error during the data analysis and computation. Despite the low percentage of the over transmitted data, there is a possibility to use this system as a Holter monitoring.

3.3 Telecardiology System Performance

The performance of the telecardiology system was analyzed by computing the transmitted data record in the modified web application running in an EC2 instance. Then, the computed data was displayed, and the ECG extracted parameters were compared to the computation result of MIT-BIH AFDB.

A record 04043/AFDB has normal heart rate variability. However, the high RMSSD increases the risk of irregular heartbeat. A total of 51 R-peaks and 44 QS-waves were detected by the cloud computing web application. On the other hand, none of the P-waves was detected due to the atrial fibrillation characteristic. Thus, the ratio of P-Wave and R-peak was 0:51. The filtered ECG signal and the pre-diagnosis results are presented in Figure 7.

Figure 7: Result of filtered ECG signal, summary, and pre-diagnosis of the Telecardiology system

3.4 Cost

In this section, two different costs will be discussed, the system service cost charged by AWS and the computation cost from the manual process.

Table 3: Transmission Duration

Transmission Duration	Attempt	Total Duration (minute)
1 minute	6	6
5 minutes	6	30
1 hour	3	180
24 hours	3	1440

3.4.1 System Service Cost. The EC2 instance costs $74 yearly and it is approximated that 7,488 patients are using ECG in the rural PHC per year. This charges $0.00988/patient for the virtual private server. In addition, the AWS charged $7 for the data transmission service with a total duration of 1656 minutes from the experiment presented in more detail in Table 3. This costs $0.004227/minute. The sum of the virtual private server cost and the data transmission service is $0.0141/minute or 2 cents.

3.4.2 Computation Cost. The computation cost was also analyzed to find its efficiency. The analysis covers the computing process from downloading the raw transmitted data, file format conversion from .json to .csv, nested array to basic array conversion, until data sorting and merging into a single file. After the calculation, the computational cost was directly proportional to the data transmission size, illustrated in Figure 8, which means the process is still inefficient. Thus, an automated computing process is required.

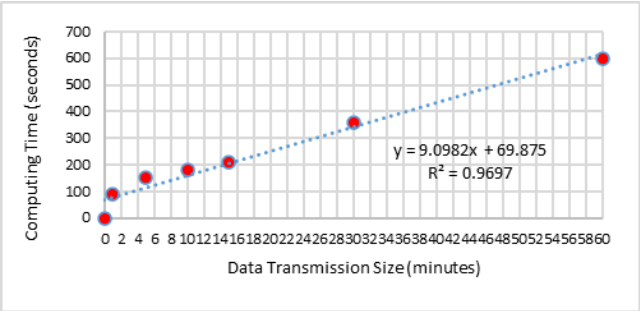

Figure 8: Data transmission size versus computing time graph

4 CONCLUSION

The goal of this paper is to develop virtual access that can conduct telecardiology for ECG analysis and provide a reliable ECG data transmission from a rural PHC to a cloud system for virtual prediagnosis of atrial fibrillation.

In this paper, the system was developed by integrating Amazon Web Service, a cloud computing service. For the data transmission, the ESP32 was utilized along with micro-SD storing the MIT-BIH AFDB ECG record data.

To sum up, the developed system was able to provide virtual access publicly for medical workers and patients from anywhere and anytime. In addition, the system can do ECG signal cloud computation and was able to detect and extract ECG features. The reliability of ECG data transmission was analyzed from the data loss. By utilizing the buffer method, 0% data loss can be achieved for durations of 1 minute, 5 minutes, and 1-hour data transmission. For 24-hour data transmission, 0.0014% extra data was observed, so the system has the potential to be a Holter monitoring with further research. The system service costs around $0.0141/minute, or 2 cents/minute

There are some limitations in this work such as the computation cost being still linear which requires automated data sorting and merging to make it more efficient. Furthermore, this system is heavily relying on the wireless network connection, thus, research on an alternative solution for offline mode is recommended for future work. Additionally, research regarding the telemedicine security system to ensure the privacy and security of the patient's personal health information is required.

Furthermore, there is a lot of potential for this developed system to be implemented for other telemedicine purposes. In addition, there is potential for the system to integrate with the wearable ECG device to obtain a better understanding of its performance in a human trial.

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REFERENCES

[1] Jill Jin. 2018. Screening for Cardiovascular Disease Risk With ECG. *JAMA* 319, 22 (June 2018), 2346. DOI:https://doi.org/10.1001/jama.2018.7311
[2] KEMENKES RI. 2014. Situasi Kesehatan Jantung. Retrieved January 21, 2022 from https://pusdatin.kemkes.go.id/download.php?file=download/pusdatin/infodatin/infodatin-jantung.pdf
[3] KEMENKES RI. 2021. *Penyakit Jantung Koroner Didominasi Masyarakat Kota*. Retrieved from https://www.kemkes.go.id/article/view/21093000002/penyakit-jantung-koroner-didominasi-masyarakat-kota.html
[4] Asri Maharani and Gindo Tampubolon. 2014. Unmet Needs for Cardiovascular Care in Indonesia. *PLoS One* 9, 8 (August 2014), e105831. Retrieved from https://doi.org/10.1371/journal.pone.0105831
[5] John R Petrie, Tomasz J Guzik, and Rhian M Touyz. 2018. Diabetes, Hypertension, and Cardiovascular Disease: Clinical Insights and Vascular Mechanisms. *Can J Cardiol* 34, 5 (May 2018), 575–584. DOI:https://doi.org/10.1016/j.cjca.2017.12.005
[6] Anna Rosiek and Krzysztof Leksowski. 2016. The risk factors and prevention of cardiovascular disease: the importance of electrocardiogram in the diagnosis and treatment of acute coronary syndrome. *Ther Clin Risk Manag* 12, (August 2016), 1223–1229. DOI:https://doi.org/10.2147/TCRM.S107849
[7] Manju Lata Sahu, Mithilesh Atulkar, Mitul Kumar Ahirwal, and Afsar Ahamad. 2021. IoT-enabled cloud-based real-time remote ECG monitoring system. *J Med Eng Technol* 45, 6 (August 2021), 473–485. DOI:https://doi.org/10.1080/03091902.2021.1921870
[8] S A Setiawan, A A Iskandar, and M Fathony. 2020. Development of Cloud Computing Algorithm for Arrhythmia Detection. In *2020 FORTEI-International Conference on Electrical Engineering (FORTEI-ICEE)*, 53–58. DOI:https://doi.org/10.1109/FORTEI-ICEE50915.2020.9249808

[9] Nirmal Sunkara and Chowdhury H. Ahsan. 2017. Hypertension in diabetes and the risk of cardiovascular disease. *Cardiovasc Endocrinol Metab* 6, 1 (2017). Retrieved from https://journals.lww.com/cardiovascularendocrinology/Fulltext/2017/03000/Hypertension_in_diabetes_and_the_risk_of.8.aspx

[10] Widyastuti Wibisana. 2019. *Penguatan Sistem Pelayanan Kesehatan*. Jakarta. Retrieved from https://www.bappenas.go.id/files/5715/9339/2399/FA_Preview_HSR_Book09.pdf#:~:text=Indonesia menganut sistem pelayanan kesehatan,dan tingkat ketiga atau tersier.&text=Program ini bersifat mandatori bagi seluruh masyarakat Indonesia.

[11] K A Zilani, R Yeasmin, K A Zubair, M R Sammir, and S Sabrin. 2018. R3HMS, An IoT Based Approach for Patient Health Monitoring. In *2018 International Conference on Computer, Communication, Chemical, Material and Electronic Engineering (IC4ME2)*, 1–4. DOI:https://doi.org/10.1109/IC4ME2.2018.8465482

[12] 2016. *Peraturan Pemerintah Republik Indonesia*. Presiden Republik Indonesia. Retrieved from https://peraturan.bpk.go.id/Home/Download/27747/PP Nomor 47 Tahun 2016.pdf

Evaluating Critical Success Factors for Implementation of Internet of Things (IoT) Using DEMATEL: A Case of Indonesian Automotive Company

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ABSTRACT

The implementation of technology is used to support the Making Indonesia 4.0 Program in various industrial sectors in Indonesia to achieve optimization of company performance. This is in line with the Indonesian Government Program through the Ministry of Industry, namely Making Indonesia 4.0. In the Making Indonesia 4.0 Program, there are 7 leading manufacturing sectors. The automotive sector is the object of this research because automotive sector is a leading player in the export of Internal Combustion Engines (ICE) and Electrified Vehicles (EVs). The technology discussed in this research is to support the Making Indonesia 4.0 Program, namely the application of the Internet of Things (IoT) to automotive companies. This research aims to evaluate the critical success factor (CSF) of IoT implementation in automotive companies in Indonesia and obtain a relationship from each dimension that becomes an evaluation of the critical success factor (CSF) of IoT implementation in automotive companies in Indonesia. In this research, the validation stage was carried out by 5 panels of experts in Indonesia who have experience and knowledge in the field of IoT application in automotive companies. The results of the research using the DEMATEL method obtained 4 critical success factors (CSF) for IoT implementation in automotive companies in Indonesia which are dispatchers who are the top priority because they have a greater influence. The four dimensions are the Marketing Dimension, Finance Regulation, and Resources. While the other 4 dimensions, namely the Dimensions of Innovation and Ideas and Resources, Operations, People, and Management, Technology became the receiver as the last priority because it received greater influence. The results of this research can be used as a reference for the automotive industry and various other industries in conducting evaluations related to the critical success factor (CSF) of IoT implementation in companies to improve company performance.

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CCS CONCEPTS

• **Multiple Criteria Decision Making**; • **Decision Analysis**; • **Technology Information System**; • **Evaluating Critical Success Factors**;

KEYWORDS

Critical Success Factors, Implementation of IoT, Automotive Companies, DEMATEL

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1 INTRODUCTION

The Government of Indonesia through the Ministry of Industry has a Making Indonesia 4.0 Initiative Program. Where the Making Indonesia 4.0 Initiative Program aims to implement Industry 4.0 technology in Indonesia. This initiative will be focused on revitalizing the Manufacturing Industry to increase Indonesia's net export contribution to GDP so that the aspiration to become a Global Top 10 GDP can be achieved. The seven sectors in the Manufacturing Industry that are the focus of this initiative are food and beverages, textiles and clothing, automotive, chemical, electronics, and 2 additional sectors, namely the Health sector and the Drugs sector [3]. In this research, the automotive sector was chosen to be the focus of the research because it is one of the sectors that contribute greatly to the economy in Indonesia, namely as the second largest automotive exporter in ASEAN [3].

In the implementation of Industry 4.0 technology through the Making Indonesia 4.0 initiative, there are nine technology pillars: *autonomous robots, simulation, system integration, internet of things, cyber security, cloud computing, additive manufacturing, augmented reality,* and *big data* [8]. One of the technological pillars that are the main layer of the implementation of Industry 4.0 is the internet of things [1]. This makes the internet of things (IoT) a technological pillar that needs to be met first to form an adequate Industry 4.0 ecosystem [1]. Internet of things technology was chosen as the focus of this research. The Internet of Things is a system of interrelated computing devices, mechanical machines, and digital objects

equipped with UIDs (Unique Identifiers) and can transfer data over the internet network [5].
The implementation of the use of IoT technology in the Manufacturing Industry can help the functions of supply chain management, operating efficiency [11], predictive maintenance [17], and inventory optimization [13]. Seeing this function, the application of IoT is projected to increase along with many industries that are already heading towards the application of Industry 4.0. The establishment of a good IoT ecosystem requires the identification of critical success factors (CSFs) so that the application of IoT can support long-term business success [8]. In addition, companies need to evaluate critical success factors (CSF) to control and provide the right decisions and obtain strategies to achieve company performance [11]. Automotive companies in Indonesia already have critical success factors (CSF) in the implementation of IoT technology to support their business activities. However, not all companies evaluate and have the right method for evaluating critical success factors (CSF) in the implementation of IoT technology applied to this company. This research contributes to obtaining the right method for evaluating critical success factors (CSF) in the implementation of IoT technology so that the company has the right priority scale and strategy for the sustainability and achievement of company performance, especially in the automotive sector.

2 LITERATURE REVIEW

This research conducted a literature review to obtain the right method for evaluating critical success factors (CSF). Evaluation of critical success factors (CSF) needs to be carried out to be able to improve company performance and provide input to the company regarding company performance to achieve the company's targets and achievements [8]. Critical success factors (CSF) as an important element in an organization to be able to achieve its goals [7]. Evaluation of critical success factors (CSF) is necessary to achieve success in a business that represents zones of the system that must be given serious attention continuously to achieve better company performance [6].

Some Multiple Criteria Decision Making (MCDM) Methods have their own advantages and disadvantages and characteristics in their use. There are several MCDM methods based on literature studies in this research to evaluate Critical success factors (CSF) among others using the AHP method, the DEMATEL method and the ANP method. In Table 1 below, a literature research related to methods for evaluating critical success factors (CSF) in companies.

Some MCDM methods such as the AHP method have a distinctive feature that the hierarchy formed considers the distribution of goals between the elements in the hierarchical structure but does not assess which elements have a greater influence on the element [21]. Whereas the ANP Method is not widely used because it is complicated [21] and only acquired dependencies between variables [22]. The DEMATEL method is capable of analyzing the mutual influence between various factors [21] and finding complicated cause and effect relationships [16]. In addition, the DEMATEL method can provide alternative ratings and find critical evaluation criteria and measure critical weights [23].

Based on literature studies related to the MCDM method this research uses the Literature Research and DEMATEL Method to evaluate critical success factors (CSF) in automotive companies in Indonesia and get the relationship between factors from complex systems later used for long-term decision making. Some of the advantages of the DEMATEL Method are obtaining a structured model form for evaluating the decision-making process [30] and obtaining visualization of the causal relationships of the sub-system by offering a causal diagram based on an understanding of the character of the problem and expert opinion [31]. Therefore, looking at the advantages of the DEMATEL Method, it is very appropriate to be used in cases and scenarios in this research.

3 METHODOLOGY

In this research, the methodology stage was divided into four parts, namely the first part of collecting critical success factors (CSF) in the implementation of IoT in automotive companies obtained by literature review and expert, the second part of the profile of expert, the third part of the stages in this research and the fourth part of the explanation of the DEMATEL Method used in this research.

3.1 Critical Success Factors (CSF) Dimension

The dimensions used in this research which are critical success factors (CSF) for IoT implementation in automotive companies are further research from researchers based on previous literature reviews [15] consisting of 8 dimensions which are criteria for evaluation indicators in IoT implementation in automotive companies in Indonesia. These dimensions consist of the Marketing Dimension (D1), the Regulatory Dimension (D2), the People and Management Dimension (D3), the Operation Dimension (D4), the Technology Dimension (D5), the Finance Dimension (D6), the Innovation and Ideas Dimension (D7) and the Resource Dimension (D8).

3.2 Profile Expert

Experts in this research consisted of 5 people who had different professions and backgrounds. Experts come from academics, practitioners in manufacturing, instructors, and the ministry of industry who become coordinators in the field of industry 4.0. Expert profiles are in table 2 below.

3.3 Research Stages

The stages in this research are divided into 4 stages. The first stage is to identify the critical success factors (CSF) of IoT implementation in automotive companies based on literature studies in previous research. The second stage is to do a consensus with experts. The third stage evaluates the questionnaire that has been filled out by experts and processes the data from the questionnaire results using the DEMATEL Method stages described in sub-chapter 3.4. Furthermore, the fourth stage of this research validates the results of processing with the DEMATEL Method to see the results of processing expert assessment data by looking at the threshold value and then making conclusions and recommendations for the results of the research.

Table 1: Literature Review For Evaluating Critical Success Factors (CSF)

No	Author	Method				Research Aim
		Literature Review	***AHP***	**DEMATEL**	**ANP**	
1	Abidin et al., 2012	-	-	-	√	*Determining and Ranking CSF Vendor Automotive in Malaysia*
2	Nilashi et al, 2014	-	-	√	√	*Evaluation of Critical Success Factors in Construction Projects*
3	Gandi et al., 2014	-	-	√	-	*Evaluating Critical Success Factors for Green Supply Chain*
4	Kumar, et al., 2015	-	√	-	-	*Evaluation of Critical Factors for Technology Transfer Process*
5	Wan & Zeng, 2015	√	-	-	-	*Key Success Model Factors for Innovation Application of IoT*
6	Kiani Mavi and Standing C,2018	-	-	√	√	*Evaluation Critical Success Factors Project Management in Construction Industry*
7	Huang et al., 2019	√	-	-	-	*Evaluation of Critical Success Factors for ERP System Implementation in Sustainable Corporations*
8	Singh and Sarkar, 2020	-	-	√	-	*Evaluating Priority CSF in Indian Automotive Industry*
9	Li et al,2020	-	-	√	-	*Analyzing Critical Success Factors in China Textile Industry*
10	This Research, 2022	√	-	√	-	*Evaluating Critical Success Factors in Indonesian Automotive Company*

Table 2: Profile of Expert

No Expert	Expert	Qualification	Year of Experience
1	Professor	Doctor	34
2.	Advisor	Master	31
3.	Head of IT	Master	7
4.	Coordinator of IR 4.0	Master	13
5.	General Manager	Master	25

3.4 The Stage of the DEMATEL Method

Decision-Making Trial and Evaluation Laboratory (DEMATEL) is one of the MCDM methods that can be used in solving causal relationship problems between factors. This method was invented at the Battelle Memorial Institute in Geneva in 1972 as a procedure for analyzing the structure of the problem and developing causal relationships between factors [20]. In its development, DEMATEL is increasingly used to visualize the structure of complex causal relationships using diagrams that can show strength.

The following are the stages of the DEMATEL method based on [20] namely:

1. Building a matrix of direct influence (by assessing the relationship between one criterion, i, against another criterion, j, as a a_ij using a scale of 0 – 4, with 0 worth "no effect", 1 worth "little influence", 2 worth "quite influential", 3 worth "influential", and 4 worth "very influential".

2. Carrying out the process of normalization of the matrix of direct influence, S, using equations (1) and (2)

$$\boldsymbol{S} = m \times \boldsymbol{A} \tag{1}$$

$$m = min\left[\frac{1}{max_i \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{max_j \sum_{i=1}^{n} |a_{ij}|}\right] \tag{2}$$

3. Obtaining the matrix of total direct influences, T, using equations (3) and (4) where I is the identity matrix. The matrix of the total direct influences is obtained from the following equation:

$$\begin{aligned} \boldsymbol{T} &= S + S^2 \ldots + S^q \\ &= S\left(I + S + S^2 \ldots + S^{k-1}\right)(I - S)(I - S)^{-1} \\ &= S\left(I - S^q\right)(I - S)^{-1} \end{aligned} \tag{3}$$

Where $q \to \infty,\ S^q = [0]_{n \times n}$, then

$$\boldsymbol{T} = \boldsymbol{S}(I - \boldsymbol{S})^{-1} \tag{4}$$

4. Counting the sum of the rows and columns of the matrix T, where the vectors R (5) and D (6) present the sum of each row and column.

$$\boldsymbol{R} = [R_i]_{n \times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1} \tag{5}$$

$$\boldsymbol{D} = \left[D_j\right]_{n \times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1 \times n} \tag{6}$$

5. R_i expresses the sum of the i-th row in the T matrix and shows the direct and indirect effects of criterion i on other criteria. Meanwhile, D_j shows the amount of direct and indirect effects received by criterion j from other criteria. When i=j, the summationR_i and D_j gives an index of both accepted and given levels of influence. In addition, if $(R_i - D_j)$ has a positive value, it indicates that other factors are affected by factor i. But if $(R_i - D_j)$ is negative, then factor i is affected by other factors.

6. Building a causal diagram by mapping the results $(R_i + D_j,\ R_i - D_j)$. Before building the diagram, it is necessary to determine the threshold value for the degree of influence where only factors in the T matrix have a value greater than the threshold value that will be shown in the diagram.

4 RESULT AND DISCUSSION

This research used the stages of the DEMATEL method, it began with determining the evaluation scale using a scale of 0-4. A value of 0 means that it has no influence or interaction. Value 2 has a moderate influence, value 3 has a strong interaction influence, and value 4 has a very strong interaction influence [23]. Furthermore, matrix calculations are carried out to obtain causal relationships between dimensions that are critical success factors (CSF) for IoT implementation in automotive companies. After calculating the matrix, a network relationship map (NRM) is built to get the relationship between dimensions.

4.1 DEMATEL Processing Results

The results of data processing are based on a recapitulation of expert opinions to obtain a Dematel Diagraph. Before obtaining the Diagraph DEMATEL is built on the value $(d_i + r_j)$ and $(d_i - r_j)$ of each criterion and subcriteria. The value $(d_i + r_j)$ indicates the degree of relationship between criteria and sub-criteria, where the higher the value indicates a stronger relationship [30]. While the value $(d_i - r_j)$ indicates the magnitude of the influence of a sub-criteria or criterion on sub-criteria or other criteria [30].

The calculation results (D-R) show the strength of influence between risk events. A positive value (D-R) indicates that the risk event has a greater influence than other risk events [16] and can be assumed to be the top priority, and is called a dispatcher. A negative (D-R) value means that the risk event receives a greater influence and can be assumed to be the last priority, called the receiver. The calculation results (D+R) show the strength of the relationship between risk events [16]. A greater value (D+R) means a larger relationship [21]. Figure 1 below shows the Diagraph DEMATEL.

Figure 1 shows the DEMATEL Diagraph obtained by looking at the values (D+R) and (D-R). The horizontal direction indicates the importance and the vertical direction indicates the relationship. For example, in the marketing dimension (D1) the value (D +R) is 3,812 and the value (D-R) is 0.110, this is because the D-R value is positive for the Marketing Dimension (D1) to be a dispatcher. This means that the Marketing Dimension (D1) has interests that are

Table 3: Calculation Result (D+R) and (D-R)

Dimension		D	R	D+R	D-R	Conclusion
Marketing	D1	1.961	1.851	3.812	0.110	dispatcher
Regulation	D2	2.173	1.980	4.153	0.192	dispatcher
People and Management	D3	2.125	2.268	4.393	-0.143	receiver
Operation	D4	2.128	2.317	4.445	-0.189	receiver
Technology	D5	2.140	2.323	4.463	-0.183	receiver
Finance	D6	2.204	1.904	4.108	0.300	dispatcher
Innovation and Ideas	D7	2.226	2.393	4.618	-0.167	receiver
Resource	D8	2.144	2.065	4.209	0.079	dispatcher

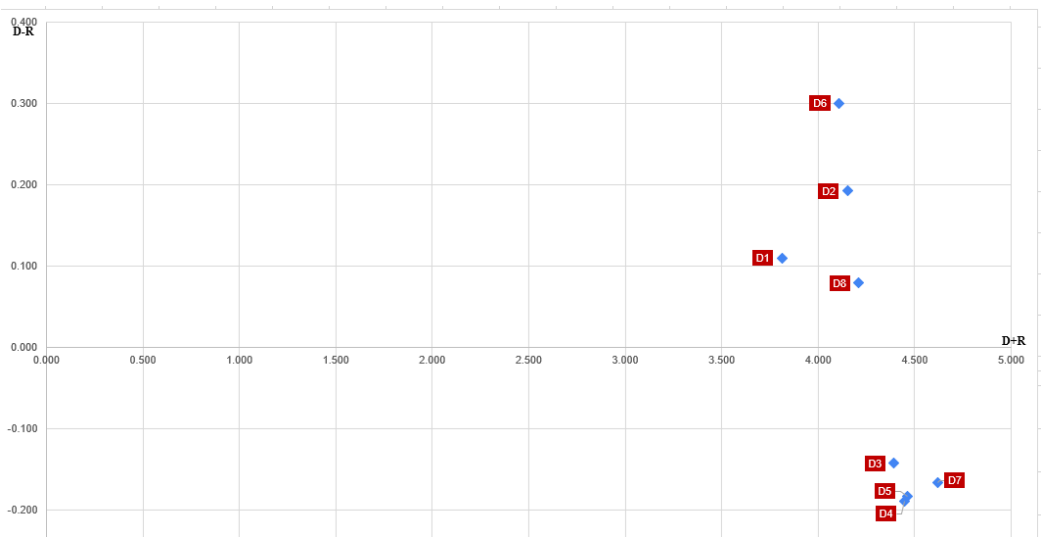

Figure 1: Diagraph DEMATEL

priorities and has a strong relationship to influence other dimensions. Meanwhile, in the People and Management (D3) Dimension of calculation using the DEMATEL Method, a value (D + R) was obtained, namely 4,393 and a value (D-R) of -0.143. In the People and Management (D3) Dimension, the value (D-R) is negative, meaning that the People and Management (D3) Dimension has a less strong relationship so that it becomes a receiver so that it is influenced by other dimensions that have a strong relationship. In addition, the People and Management (D3) dimension is also not a top priority for companies.

The results showed that 4 dimensions become dispatchers, namely the Dimensions of Marketing, Regulation, Finance, and Resources. This is because these 4 dimensions based on expert opinions are the most important and are a priority in determining the critical success factors (CSF) of IoT implementation in automotive companies in Indonesia. The company in evaluating the performance of the activities of each department has its dimensions or criteria. Important criteria for companies are used to be the company's priority in determining strategies and evaluation materials regularly [28] to minimize the occurrence of risks [27].

Whereas the other 4 dimensions, namely the Dimensions of People and Management, Operation, Technology and Innovation, and Ideas, become receivers. According to experts, these four dimensions are strongly influenced by internal and external factors of the company. External factors such as demand from customers who want products of good quality [10] and prompt delivery [12] and internal factors such as the selection of the right technology in the application of Industry 4.0 to support the government. There are several things to consider including technology identification, technology utilization, and technology protection [12]. All of these factors are considered by the management team to make the right strategic decisions in achieving optimization of company performance achievements [18].

4.2 Network Relationship Map (NRM)

The result of data processing using DEMATEL is the Network Relationship Map (NRM). After getting the values (D +R) and (D-R) and then creating a DEMATEL Diagraph, a Network Relationship Map (NRM) can be created, with the arrow direction represented by the

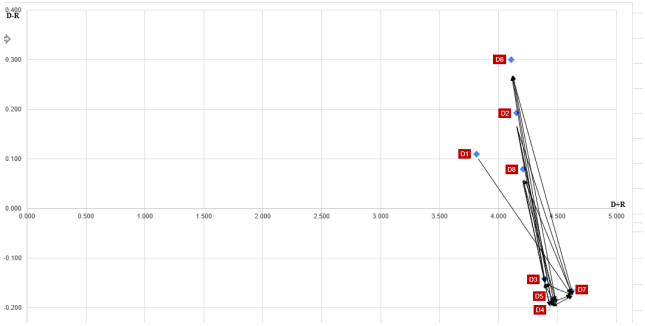

Figure 2: Network Relationship Map (NRM)

value on the matrix that exceeds the threshold value. The Threshold Value is the threshold value of a parameter to form a network [28]. In this research, the Global Threshold Value was obtained, which was 0.274. After that make sure the threshold value in the next stage makes the network relationship map (NRM). DEMATEL Method is the valid method for knowing the relationship between factors. We can analyze the relationship between each dimension with the other. We can make the decision and make strategy based on calculating DEMATEL Method. In this research, the network relationship map (NRM) is shown in Figure 2 below.

Figure 2 shows the position of each dimension that forms the network on the Network Relationship Map (NRM). The results showed that the Innovation and Ideas (D7) Dimension had the strongest relationship when compared to the other 7 dimensions. This is because the Innovation and Ideas (D7) Dimension has the largest value (D + R) when compared to the other 7 dimensions. In addition, the Innovation and Ideas (D7) Dimension is also a priority and reason for companies to switch to using IoT to support their business processes towards digitalization. This is done by the company to obtain effective and efficient business processes so that it can achieve optimal company performance (4) and company sustainability (20).

The Finance dimension (D6) has the strongest influence when compared to the other 7 dimensions. The Finance Dimension (D6) has a value (D-R) that has a positive value and the value is the largest when compared to the other 3 dimensions that have a positive value. The Finance Dimension (D6) affects the implementation of the Making Indonesia 4.0 (3) Program so that the financial aspect is considered by the company to use technology 4.0 in its business processes. The company considers from the financial condition of the company whether it has allocation and financial planning to purchase technology 4.0 devices (15) in addition to that it is also needed for employee training and system maintenance costs (15) and most importantly the company considers in implementing technology 4.0 to help its business processes whether it has an impact on the company is related to profit for the company because it is for the sustainability of the company [19].

5 CONCLUSION AND RECOMMENDATION

This research has been carried out starting from a literature review in identifying the dimensional criteria that become critical success factors (CSF) for IoT implementation in automotive companies in Indonesia. There are 8 dimensions, namely the Marketing Dimension (D1), the Regulation Dimension (D2), the People and Management Dimension (D3), the Operation Dimension (D4), the Technology Dimension (D5), the Finance Dimension (D6), the Innovation and Ideas Dimension (D7) and the Resources Dimension (D8).

In the dimension innovation and ideas (D7) have the strongest relationship when compared to the other 7 dimensions balanced with strong relationships and interests due to value. The Finance dimension (D6) has the strongest influence when compared to the other 7 dimensions. The results of this research can be an evaluation for other automotive companies to get a critical success factor (CSF) for IoT implementation in automotive companies. The novelty in this research is to identify the ciritcal success factors for the implementation of IoT in Indonesian Automotive Companies that have not been carried out in previous study. In addition, a practical contribution from this research is to obtain critical success factors for IoT implementation can be used in automotive companies and other manufacturing sectors in evaluating and designing performance indicators so as to improve caompany performance in the long term.

Suggestions and recommendations for the next research are that this research has not included sub-dimensions that are sub-criteria in evaluating critical success factor (CSF) and also has not determined the priority scale on each dimension and sub-dimension accompanied by testing using quantitative methods to obtain optimal results.

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REFERENCES

[1] M. Hermann, T. Pentek, and B. Otto, "Design Principles for Industrie 4.0 Scenarios," in *Proc. HICSS*, Hawaii, USA, 2016, pp. 3928–3937.
[2] Kumar R., Singh R K. & Shankar R. (2015). Critical success factors for the implementation of supply chain management in Indian small and medium enterprises and their impact on performance. *IIMBManagement Review.*
[3] Kemenrian Perindustrian (2020).Kemenprin Andalkan 7 Sektor Industri Selamatkan Pertumbuhan Ekonomi Kuartal II. ttps://www.erdeka.com/uang/kemenperin-andalkan-7-sektor-industri-ini-selamatkan-pertumbuhan-ekonomi-kuartal-ii.html. (access on 10 June 2022).
[4] Attaran, M. (2012). Critical success factors and challenges of implementing RFID in supply chain management. *Journal of Supply Chain and Operations Management*, *10*(1), 144–167.
[5] B, R. R. (2018). A Comprehensive Literature Review on Data Analytics in IIoT (Industrial Internet of Things). *Helix*, *8*(1), 2757–2764. Htt ps://doi.org/10.29042/2018-2757-2764.
[6] Finney, S., & Corbett, M. (2014). ERP Implementation: A Compilation and Analysis of Critical Success Factors. *Business Process Management Journal, 13*(3), 329–347.
[7] Freund, Y. P. (1994). Critical Success Factors. *Planning Review*, *16*(4), 20–23.
[8] Kementrian Perindustrian (2018*).Empat Strategi Indonesia Masuk Revolusi Industri 4.0* http://www.kemenperin.go.id/artikel/17565/Eat (access on 9 March 2019).
[9] Ju, J., Kim, M. S., & Ahn, J. H. (2016). Prototyping Business Models for IoT Service. *Procedia Computer Science*, *91*(Itqm),882–890.
[10] Kumar, S., Luthra, S., Haleem, A., Mangla, S. K., & Garg, D. (2015). Identification and evaluation of critical factors to technology transfer using AHP approach. *InternationaStrategic Management Review, 3*(1–2), 24–42.
[11] Kiba-Janiak, M. (2016). Key Success Factors for City Logistics from the Perspective of Various Groups of Stakeholders. *Transportation Research Procedia*, *12*(June 2015), 557–569.
[12] Wan, J., & Zeng, M. (2015). Research on Key Success Factors Model for Innovation Application of Internet of Things with Grounded Theory. *WHICEB 2015 Proceedings*, 647–654.

[13] Sadique, K. M., Rahmani, R., & Johannesson, P. (2018). Towards security on internet of things: Applications and challenges in technology. *Procedia Computer Science*, *141*, 199–206. https://doi.org/10.1016/j.procs.2018.10.168.

[14] Talib, M. S. A., Hamid, A. B. A., & Thoo, A. C. (2015). Critical success factors of supply chain management: A literature survey and Pareto analysis. *EuroMed Journal of Business*, *10*(2), 234–263.

[15] Hakim, I. M., Singgih, M. L., & Gunarta, I. K. (2021). Critical success factors for implementation of internet of things (IoT) in automotive companies: A literature review. In *Proceedings of the 11th Annual International Conference on Industrial Engineering and Operations Management, 2021,* pp. 5199-520.

[16] Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D. Evaluating factors in implementation of successful green supply chain management using DEMATEL: a case research. International Strategic Management Review, 2015.

[17] Landherr, M., Schneider, U., & Bauernhansl, T. (2016). The Application Center Industrie 4.0 - Industry-driven Manufacturing, Research and Development. *Procedia CIRP*, *57*, 26–31.

[18] Nah .F.F., & Lau.L.J. (2001). Critical Factors For Successful Implementation Of Enterprise Systems. Business Process Management Journal, Vol. 7 No. 3, 2001,pp. 285-296. MCB University Press, 1463-7154.Emerald Library.

[19] Huang.Y.S., Chiu.A.A.,Chao.P.C & Arniati.A.(2019). Critical Success Factors in Implementing Enterprise Resource Planning Systems for Sustainable Corporations. pp 11,6785. mdpi.com/journal/sustainability.

[20] Yang, J.L. and Tzeng, G.H. 2011. An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Systems with Applications*. 38, 3 (2011), 1417–1424. DOI:https://doi.org/10.1016/j.eswa.2010.07.048.

[21] Zhao, G., Irfan Ahmed, R., Ahmad, N., Yan, C., & Usmani, M.S. (2021). Prioritizing critical success factors for the sustainable energy sector in China: A DEMATEL approach. *Energy Strategy Reviews*, *35*(November 2020), 100635. https://doi.org/10.1016/j.esr.2021.100635.

[22] Yang, C. L., & Huang, R. H. (2011). Key success factors for online auctions: Analysis of auctions of fashion clothing. *Expert Systems with Applications*, *38*(6), 7774–7783. https://doi.org/10.1016/j.eswa.2010.12.130.

[23] Yang, J. L., & Tzeng, G. H. (2011). An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Systems with Applications*, *38*(3), 1417–1424.https://doi.org/10.1016/j.eswa.2010.07.048.

[24] Abidin, A. S. Z., Muslimen, R., & Yusuff, R. M. (2012). Determining and ranking of CSFs for design capabilities development in Malaysian automotive vendors. *Advanced Materials Research*, *433–440*, 2212–2218. https://doi.org/10.4028/www.scientific.net/AMR.433-440.2212.

[25] Chen, F. H., Hsu, T. S., & Tzeng, G. H. (2011). A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP. *International Journal of Hospitality Management*, *30*(4), 908–932. https://doi.org/10.1016/j.ijhm.2011.02.001.

[26] Hsu, C. W., & Yeh, C. C. (2017). Understanding the factors affecting the adoption of the Internet of Things. *Technology Analysis and Strategic Management*, *29*(9), 1089–1102. https://doi.org/10.1080/09537325.2016.1269160

[27] Li, Y., Barrueta Pinto, M. C., & Diabat, A. (2020). Analyzing the critical success factor of CSR for the Chinese textile industry. *Journal of Cleaner Production*, *260*, 120878. https://doi.org/10.1016/j.jclepro.2020.120878.

[28] Nilashi, M., Zakaria, R., Ibrahim, O., Majid, M. Z. A., Zin, R. M., & Farahmand, M. (2015). MCPCM: A DEMATEL-ANP-Based Multi-criteria Decision-Making Approach to Evaluate the Critical Success Factors in Construction Projects. *Arabian Journal for Science and Engineering*, *40*(2), 343–361. https://doi.org/10.1007/s13369-014-1529-1.

[29] Singh, P. K., & Sarkar, P. (2020). A framework based on fuzzy Delphi and DEMATEL for sustainable product development: A case of Indian automotive industry. *Journal of Cleaner Production*, *246*, 118991. https://doi.org/10.1016/j.jclepro.2019.118991

[30] Supeekit, T., Somboonwiwat, T., & Kritchanchai, D. (2016). DEMATEL-modified ANP to evaluate internal hospital supply chain performance. *Computers and Industrial Engineering*, *102*, 318–330. https://doi.org/10.1016/j.cie.2016.07.019.

[31] Kiani Mavi, R., & Standing, C. (2018). Critical success factors of sustainable project management in construction: A fuzzy DEMATEL-ANP approach. *Journal of Cleaner Production*, *194*.

[32] Tseng, M. L., (2008), "Application of ANP and DEMATEL to evaluate the decision making of municipal solid waste management in Metro Manila", *Environment Monitoring Assessment* (156), *page* 181-197.

Controlling The Performance of Anti-lock Braking System at Various Tracks and Vehicle Conditions

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ABSTRACT

The anti-lock braking system (ABS) is a control system that allows the vehicle's wheels to slow down without locking, stabilizes the steering wheel during harsh braking, and reduces stopping distance. Using a complete motorbike model, computer simulation is used to analyze ABS performance. ABS is currently an integral feature of the automotive system that provides added safety. To address the issue of severe nonlinearity in ABS design, controllers such as PID and bang-bang controllers are trying to regulate the longitudinal slip of the wheels during braking are required. It also employs diverse road conditions and vehicle circumstances/configurations in this article. MATLAB and Simulink are used to create the results of the simulated comparison between various situations and settings.

CCS CONCEPTS

• **Computer systems organization**; • **Embedded and cyber-physical systems**; • **Sensors and actuators**;

KEYWORDS

Anti-lock Braking System, PID Control, Bang-bang Control, Vehicle Dynamic, System Control, MATLAB

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1 INTRODUCTION

By avoiding excessive wheel slide, managing the vehicle during heavy braking maneuvers, and decreasing stopping distance, an anti-lock braking system (ABS) offers the best real-time braking force. Nonlinearity in vehicle braking dynamics such as friction between the surface of the brake pad and disc brake incorporated with temperature changes while in braking maneuver, variations in model parameters over a wide range of spectra such as variations in road surface conditions and vehicle conditions, controller operation at unstable equilibrium points in optimal performance, and sensor signal uncertainty all cause issues during the design of ABS brakes. Many challenges occur in the design of the ABS controller as a result of these numerous characteristics. [1-3]

ABS now employs a control unit that continually evaluates the velocity of all wheels, each of which is equipped with a speed sensor. When the velocity of the wheels is locked, a control signal (PID control) is transmitted to lower and raise the braking pressure on the corresponding wheels within milliseconds. As a result, wheel slip is kept at its ideal amount, equivalent to the maximum coefficient of friction, ensuring consistent rotation of the wheels and steering maneuverability of the vehicle even during harsh braking moments in crucial scenarios. [4]

2 METHOD

In this paper, the model parameters used for computer simulation are motorcycles that de-accelerate in a straight line with different road and weather conditions, namely dry road conditions in sunny weather and wet road conditions in rainy weather. The type of road that will be used for the simulation is asphalt road in both dry and wet conditions, each road condition has a different coefficient of friction and slip ratio [4-6] based on the mu-slip look-up table 1. Dry asphalt has a relatively high coefficient of friction ratio with longitudinal slip, which allows it to offer a strong grip on the surface of vehicle tires. While the coefficient of friction to longitudinal slip ratio is relatively low, it is a feature of wet asphalt that does give a low grip on the surface of vehicle tires.

This simulation uses a Ducati Panigale V4 motorcycle model (Figure 2) as the main parameter, where the parameters used to consist of wet weight, wheel & tire dimensions, disc brake dimensions, and caliper piston dimensions. This paper also uses two different disc brake configurations, namely the first to use a metal alloy composite disc brake made of silicon carbide reinforced aluminum-copper alloy composite (Al-Cu/SiC) or aluminum matrix composite (AMC) (Figure 3) and carbon fiber ceramic disc brake made of carbon fiber reinforced carbon-silicon carbide (Cf/C-SiC) (Figure 4). Each disc material has a different coefficient of friction characteristics, based on other studies [9-11] stated that the average friction coefficient of metal alloy composite disc brake Al-Cu/SiC has a friction coefficient value of 0.44. Meanwhile, the carbon fiber ceramic disc brake Cf/C-SiC with a high fraction of SiC/Si (~53.1%), has a friction coefficient of 0.52.

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2.1 Vehicle Dynamics

The performance of a moving object is determined by a variety of variables. These variables are, in general, speed, acceleration/deceleration, frictional force, normal force, and motion force. A linearly of moving object has a frictional force, a normal force, a kinetic force, a linear velocity, and a linear acceleration. However, if a moving object is in the shape of a circle, sphere, or has wheels, angular variables such as angular velocity, angular acceleration, the moment of inertia, torque, and angular momentum will grow from these variables.

A schematic showing the dynamics of the vehicle's wheels traveling forward is shown in Figure 4. There is a mass m with a wheel radius R revolving at an angular velocity ω, resulting in a rotating wheel motion that drives a mass load with the vehicle's linear velocity V_v and the wheels linear velocity V_w. When an object moves, it must generate a reaction force in the opposite direction of the moving object. Friction and air drag are the linear response forces of a moving vehicle. The angular response force then acts as a braking force.[12]

The dynamics of vehicle braking can be derived using a mathematical approach [1] [2] [11-17] as in the row of the Equation below:

The torque balance in moving wheel mechanics is represented by Equation 1, where τ_w is the wheel torque, τ_t is the vehicle torque, and τ_b is the braking torque.

$$\sum \tau_w = \tau_v - \tau_b \tag{1}$$

Equation 2 provides a complete explanation of wheel torque, vehicle torque, and braking torque for each J inertia Equation minus the α_w wheel angular acceleration.

$$\tau_w = J - \alpha_w$$
$$\tau_v - \tau_b = J - \alpha_w \tag{2}$$

In Equation 3, the vehicle torque is expressed as F_f friction force multiplied by the R radius of the tire. Where the tire radius can be found by calculating the wheel dimension criteria from Table 1 where H is tire side-wall height, AR is tire aspect ratio, W is tire width, D is rim diameter, and d_w is wheel diameter

$$\tau_v = F_f\ R$$
$$H = \frac{AR \cdot W}{100}$$
$$d_w = D + 2H$$
$$R = \frac{d_w}{2}$$
$$F_f\ R - \tau_b = J - \alpha_w \tag{3}$$

Equation 4 demonstrates that Equation $F_f = \mu_s N$ can be substituted into Equation 4 from Equation 3 where μ_s is longitudinal coefficient of friction and N is weight.

$$F_f = \mu_s N$$
$$\mu_s\ N\ R - \tau_b = J - \alpha_w \tag{4}$$

Equation 5 is obtained by substitution of Equation $N = m\ g$ into Equation 4 where m is the mass of the vehicle and g is gravitational force.

$$N = m\ g$$
$$\mu_s\ m\ g\ R - \tau_b = J - \alpha_w$$
$$\alpha_w = \frac{\mu_s\ m\ g\ R - \tau_b}{J} \tag{5}$$

Equation 6 is obtained by substitution of the brake actuator Equation which contains braking friction coefficient μ_b, piston brake force F_p, brake caliper radius r_e, inner brake caliper radius r_i, outer brake caliper radius r_o, pressure of master cylinder P_m, and area of the caliper piston A_p into Equation 5.

$$\tau_b = \mu_b\ F_p\ r_e$$
$$r_e = \frac{r_i + r_o}{2}$$
$$F_p = P_m\ A_p$$
$$\alpha_w = \frac{\mu_s\ m\ g\ R - \left(\mu_b\ P_m\ A_p\ r_e\right)}{J} \tag{6}$$

Longitudinal Velocity

Equation 7 is the vehicle angular velocity derived from the integral of α_v vehicle angular acceleration and Equation 8 is the wheel angular velocity derived from the integral of α_w wheel angular acceleration.

$$v_v = R\ \omega_v \tag{7}$$
$$v_w = R\ \omega_w \tag{8}$$

Longitudinal Slip

The longitudinal slip λ value is calculated by dividing the vehicle longitudinal velocity v_v by the wheel longitudinal velocity v_w in Equation 9.

$$\lambda = \frac{v_v}{v_w} \tag{9}$$

Based on the derivation of the formula, the working principle of ABS is to balance wheel torque with vehicle torque and braking torque as depicted in Figure 4. Rotating wheels with tires that have good F_f traction with the road surface will provide stability in driving. Wheels that lock during hard braking are caused by the wheels losing the angular velocity ω_w and the braking torque τ_b being applied is too large so that it locks the spinning wheels.

2.2 PID Control with Bang-bang Control

The PID control system is a common closed-loop control system that works well in real-time operations. PID, on the other side, cannot function properly in the presence of uncertainty and non-linearity in the system. PID control, as a traditional control technique, is widely employed as the primary control system module because it has the properties of a limited number of calculations, real-time calculations, system performance stabilization, and simplicity of implementation. PID control is a conventional controller that has been developed to calculate the error acquired from the real model with the desired input. PID control contains three sorts of parameters that can be set based on a system's objectives and conditions. Each parameter functions in a different technique to reduce errors from the factory model. The PID control can be described as: P = Proportional, I = Integral, D = Derivative. Where is the PID control algorithm as:

$$u\ (t) = K\left(e\ (t) + \frac{1}{T_i}\int_0^t e\ (t)\ dt + T_d\frac{de\ (t)}{dt}\right)$$

Where y is the measured process variable, y_{sp} is the setpoint variable, u is the control action and e is the control error $e = y_{sp} - y$. Thus, the control action is a linear combination of three terms: the

Table 1: Vehicle specification of Ducati Panigale V4 (Ducati Motor Holding S.p.A. and Brembo S.p.A.)

Parameters	Value
Wet weight	193 kg
Front tire dimension	120/70-17
Rear tire dimension	200/60-17
Front disc brake dimension	330 x 72 mm x 2
Rear disc brake dimension	245 x 83 mm x 1
Front caliper piston diameter	30 mm x 8 piston
Rear caliper piston diameter	34 mm x 2 piston

P-term (which is proportional to the error), the I-term (which is proportional to the error integral), and the D-term (which is proportional to the derivative of the error). The controller parameters are proportional gain K, integral time T_i, and derivative time T_d [18] [19].

Bang-Bang control, also known as rapid control, has several applications in manufacturing, aerospace, and automotive. Bang-bang control can eliminate large errors, improve tracking convergence rate, the algorithm is simple and convenient, but because the characteristics of bang-bang control are vulnerable to causing system instability, after the error is less than a certain range, the use of other control methods to ensure system accuracy, including combining bang-bang control with PID control is recommended. [20-22].

The Bang-Bang controller outperforms PID control in terms of dynamic performance, particularly in resisting changes in setpoint values and the impacts of major disturbances. However, bang-bang controllers shake in a static state. However, when the deviation is minor, the control quality is poorer than with PID control. On the other hand, in a PID control situation, it is difficult for the PID control to assure control performance in the case of a large disturbance. However, when the deviation scope is limited, it has higher static performance and a stronger capacity to minimize steady-state error. As a result, for ABS to deal with nonlinearity in the real-time calculation., the two benefits of bang-bang control must be combined with PID control.

The engine control unit (ECU) gathers, amplifies, and filters sensor information to determine wheel velocity and acceleration. This unit also uses the velocity of two diagonally opposing wheels to compute the vehicle's estimated velocity. By comparing these two reference velocities with the appropriate wheel velocity, the slip of each wheel is calculated. The wheel acceleration and wheel slip signals are intended to warn the ECU of potential locking tendencies. The microprocessor, which is a PID control and bang-bang control, responds to such a warning by sending a signal to the pressure modulator to trigger the hydraulic pressure valve, which modulates the braking pressure in the individual wheel brake calipers. The ECU also has many fault-recognition functions for the complete ABS, including a wheel speed sensor, control pressure valves, a wire harness, and the ECU module itself. When a recognized flaw or problem in the system is detected, the ECU responds by shutting off a faulty element of the system or turning off the entire ABS [23].

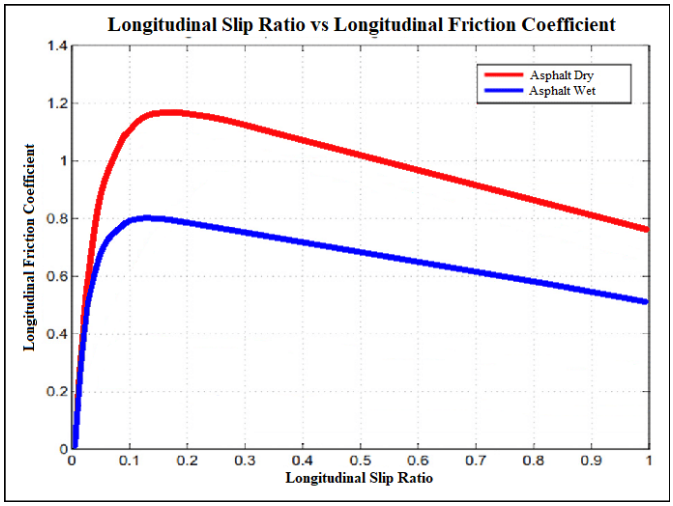

Figure 1: Mu-slip look-up table [4]

Figure 2: Ducati Panigale V4 (Ducati Motor Holding S.p.A.) [1]

Figure 3: The real picture of motorcycle disc brake (above) Metal Alloy-Composite Motorcycle Disc Brake (Brembo S.p.A.) [26] and (below) Carbon Fiber-Ceramic Motorcycle Disc Brake (SICOM T-Drive) [28]

Table 2: Simulation parameters of the vehicle (Ducati Motor Holding S.p.A. and Brembo S.p.A.) [26, 27]

Parameters	Value
Gravitational force	9,806 m/s^2
Initial velocity	50 m/s
The inertia of all-wheel	4,077 kg*m^2
The pressure of a master cylinder	1,9 MPa
Area of brake caliper	48,87 m^2
Disc brake radius	0,32 m
Wheel radius	0,636 m
Full load weight	255 kgf

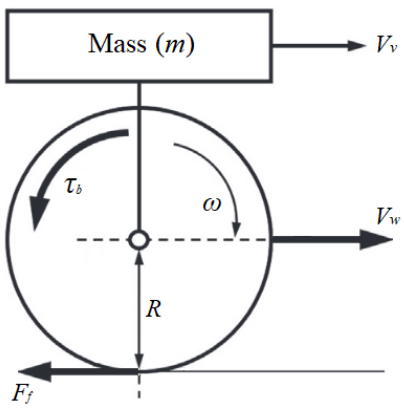

Figure 4: Single wheel dynamics [8]

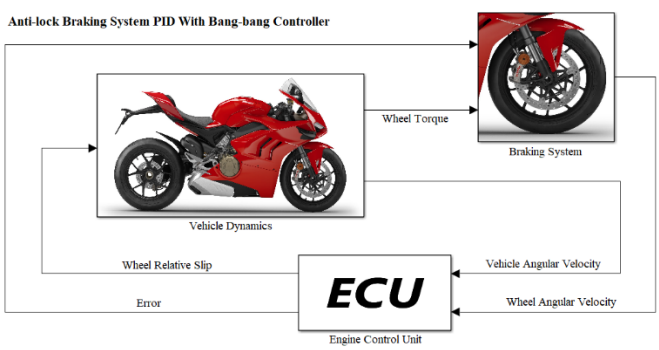

Figure 5: Schematic diagram of Anti-lock Braking System

3 RESULTS

The simulation is running using MATLAB and Simulink to build the ABS braking system. The simulation was carried out with 4 different conditions, the first condition is the motorcycle using a carbon-fiber ceramic disc brake riding on a dry track with sunny weather (CSD), the second condition is the motorcycle using a metal alloy composite disc brake riding on a dry track with sunny weather (MSD). The third condition is the motorcycles using carbon-fiber ceramic disc brakes riding on a wet track with rainy weather (CRW), the fourth condition is the motorcycles using metal alloy composite disc brakes riding on a wet track with rainy weather (MRW).

The braking performance of ABS brakes in 4 different conditions as shown in Figure 6(a), it can be seen that the relative slip performance of motorcycles using carbon fiber ceramic disc brakes in dry conditions (CSD) is able to beat the braking performance of motorcycles using metal alloy (MSD). , where the use of carbon fiber ceramic disc brakes has a higher coefficient of friction than metal alloy disc brakes plus dry road weather conditions produce the best braking performance. Then, due to wet road conditions, motorcycles with carbon fiber ceramic disc brakes in wet conditions (CRW) were able to outperform motorcycles with metal alloy composite disc brakes in the same conditions (MRW), but they were still not as good as motorcycles with carbon fiber ceramic disc brakes in dry conditions (CSD). In a different analysis as shown in Figure 6(b), motorcycles using carbon fiber ceramic disc brakes in dry conditions (CSD) resulted in very short braking distances compared to other motorcycle braking configurations and scenarios (MSD), (CRW), and (MRW). This short braking distance is caused by the coefficient of friction between the tire surfaces and different road surfaces and the coefficient of friction between the surface of the brake lining and the surface of the brake disc, where the use of carbon fiber ceramic disc brakes has the highest coefficient of friction compared to metal alloy disc brakes which result in better braking performance and maximum performance for the use of carbon fiber ceramic disc brakes in dry conditions.

The next part discusses the motorcycle's vehicle speed in the various conditions depicted in Figure 6. (c). Among the other cases, using carbon fiber ceramic disc brakes in dry weather has the least amount of time for braking. This is because carbon fiber ceramics have a higher coefficient of friction between the surface of the brake disc and the surface of the brake pads than metal alloy disc brakes. Figure 6(d) shows the performance of the angular velocity of the motorcycle wheels when braking using ABS, there is something different in the graph which shows the braking performance of motorcycles on dry track conditions both using carbon-fiber ceramic disc brakes and metal alloy composites shows excellent anti-locking performance, where the wheels didn't lock so that the resulting braking is very stable, there is no slip on the road surface with the tires. However, when both types of disc brakes hit a wet track, the ABS brakes do not function properly, resulting in wheel angular velocity that locks and slips occurring at the near end of braking.

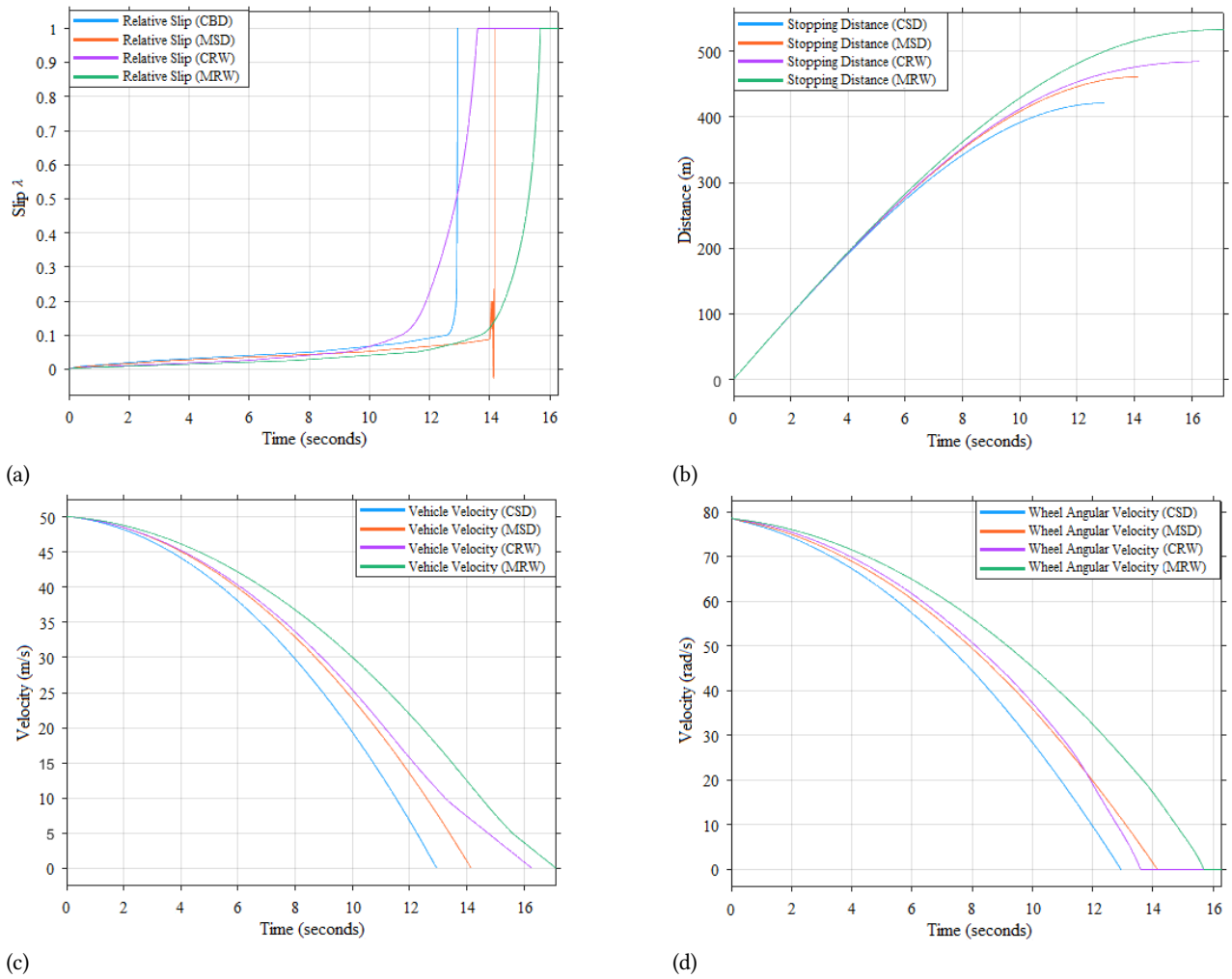

Figure 6: Comparing simulation results in braking performance with ABS PID control and bang-bang control in (a) relative slip, (b) stopping distance, (c) vehicle linear velocity, and (d) wheel angular velocity

4 CONCLUSION

Based on the results of the computer simulation, it is following statements from other studies [9] that there is a decrease in the coefficient of friction on the disc brakes when passing through a wet track where water from the rain covers both brake discs which produce a hydrodynamic lubrication layer on the surface of the disc brake. Similarly, the surface of the tire that passes through the wet tracks where the hydrodynamic lubricant layer that covers the surface of the tire and the road surface affects the decrease in the coefficient of longitudinal friction between the track/road surface and the tire. Humidity also plays an important role in braking performance especially in rainy weather where the humid is increases then the friction coefficient decreases compared with sunny weather where the humid is decreased resulting in the increases of friction coefficient [24]. The use of ABS with carbon-fiber ceramic brake discs can increase braking performance to reduce braking distance compared to metal alloy composite brake discs in both dry weather and rainy weather. However, performance is reduced when using ABS with carbon-fiber ceramic and metal alloy discs brake on wet tracks in rainy weather compared to braking performance using ABS with carbon-fiber ceramic and metal alloy composite on dry tracks in sunny weather. This study excludes temperature and physical surface changes in disc brake material under braking conditions, temperature and physical surface changes in tire material under braking conditions, and the usage of a conventional control system. It will be more accurate and disclose more information if these variables are addressed for future study.

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REFERENCES

[1] Yadav, D. K. (2015). MODELING AN INTELLIGENT CONTROLLER FOR ANTI-LOCK BRAKING SYSTEM. International Journal of Technical Research and Applications, 3(4), 122–126.

[2] More, H. R., Digrase, A. A., & Wayse, A. V. (2017). Linear PID control technique for single wheel ABS (anti-lock braking system) of motorcycle. 2017 2nd International Conference for Convergence in Technology (I2CT).

[3] V., Rau, Ahmad, F., Hassan, M.Z., and Hudha, K. (2014). IDENTIFICATION OF INTELLIGENT CONTROLS IN DEVELOPING ANTI-LOCK BRAKING SYSTEM. Journal of Advanced Manufacturing Technology (JAMT) 7(1). https://jamt.utem.edu.my/jamt/article/view/27.

[4] Rosinova, D., & Kozakova, A. (2020). Laboratory ABS Control: Fuzzy or PID Controller? 2020 Cybernetics & Informatics (K&I). https://doi.org/10.1109/ki48306.2020.9039796

[5] Saha, S., & Amrr, S. M. (2020). Design of slip-based traction control system for EV and validation using co-simulation between Adams and Matlab/Simulink. SIMULATION, 96(6), 537–549. https://doi.org/10.1177/0037549719897834

[6] Zhao, Y. Q., Li, H. Q., Lin, F., Wang, J., & Ji, X. W. (2017). Estimation of Road Friction Coefficient in Different Road Conditions Based on Vehicle Braking Dynamics. Chinese Journal of Mechanical Engineering, 30(4), 982–990. https://doi.org/10.1007/s10033-017-0143-z

[7] Podrigalo, M., Klets, D., Sergiyenko, O., Gritsuk, I. V., Soloviov, O., Tarasov, Y., Baitsur, M., Bulgakov, N., Hatsko, V., Golovan, A., Savchuk, V., Ahieiev, M., & Bilousova, T. (2018). Improvement of the Assessment Methods for the Braking Dynamics with ABS Malfunction. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1881

[8] Bian, G., & Wu, H. (2015). Friction performance of carbon/silicon carbide ceramic composite brakes in ambient air and water spray environment. Tribology International, 92, 1–11. https://doi.org/10.1016/j.triboint.2015.05.023

[9] Maleque, M. A., Dyuti, S., & Rahman, M. (2010). Material selection method in design of automotive brake disc. Materials Science.

[10] Ma, X., Fan, S., Sun, H., Luan, C., Deng, J., Zhang, L., & Cheng, L. (2020). Investigation on braking performance and wear mechanism of full-carbon/ceramic braking pairs. Tribology International, 142, 105981. https://doi.org/10.1016/j.triboint.2019.105981

[11] Pauwelussen, J. P. (2015). Nonsteady-State Tire Behavior. Essentials of Vehicle Dynamics, 75–109. https://doi.org/10.1016/b978-0-08-100036-6.00003-0

[12] Chen, C. P., & Chiang, M. H. (2018). Mathematical Simulations and Analyses of Proportional Electro-Hydraulic Brakes and Anti-Lock Braking Systems in Motorcycles. Actuators, 7(3), 34. https://doi.org/10.3390/act7030034

[13] Ting, W. E., & Lin, J. S. (2005). NONLINEAR BACKSTEPPING DESIGN OF ANTI-LOCK BRAKING SYSTEMS WITH ASSISTANCE OF ACTIVE SUSPENSIONS. IFAC Proceedings Volumes, 38(1), 97–102. https://doi.org/10.3182/20050703-6-cz-1902.01904

[14] Dardanelli, A., Alli, G., & Savaresi, S. M. (2010). Modeling and control of an electromechanical brake-by-wire actuator for a sport motorbike. IFAC Proceedings Volumes, 43(18), 524–531. https://doi.org/10.3182/20100913-3-us-2015.00072

[15] Saraiev, O., & Gorb, Y. (2018). A Mathematical Model of the Braking Dynamics of a Car. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1893

[16] García-León, R. A., Quintero-Quintero, W., & Gomez-Camperos, J. A. (2020). Mathematical analysis of the dynamic behavior three motorcycle disc brakes. Journal of Physics: Conference Series, 1708(1), 012025. https://doi.org/10.1088/1742-6596/1708/1/012025

[17] Cattabriga, S., de Felice, A., & Sorrentino, S. (2019). Patter instability of racing motorcycles in straight braking manoeuvreVehicle System Dynamics, 59(1), 33–55. https://doi.org/10.1080/00423114.2019.1663389

[18] Borase, R. P., Maghade, D. K., Sondkar, S. Y., & Pawar, S. N. (2020). A review of PID control, tuning methods and applications. International Journal of Dynamics and Control, 9(2), 818–827. https://doi.org/10.1007/s40435-020-00665-4

[19] Chen, S., Zhao, J., & Qian, J. (2007). A Design Method of Bang-Bang and PID Integrated Controller Based on Rough Set. Fourth International Conference on Fuzzy Systems and Knowledge Discovery (FSKD 2007). https://doi.org/10.1109/fskd.2007.17

[20] Meng, Q., Wang, Y., Xu, F., & Shi, X. (2015). Control strategy of cement mill based on Bang-Bang and fuzzy PID self-tuning. 2015 IEEE International Conference on Cyber Technology in Automation, Control, and Intelligent Systems (CYBER). https://doi.org/10.1109/cyber.2015.7288250

[21] Qui, N. T., & Wachsmuth, D. (2018). Stability for bang-bang control problems of partial differential equations. Optimization, 67(12), 2157–2177. https://doi.org/10.1080/02331934.2018.1522634

[22] Li, J., Wen, B., & Wang, H. (2019). Adaptive Virtual Inertia Control Strategy of VSG for Micro-Grid Based on Improved Bang-Bang Control Strategy. IEEE Access, 7, 39509–39514. https://doi.org/10.1109/access.2019.2904943

[23] Gowda V., D., & A. C., R. (2017). Slip Ratio Control of Anti-Lock Braking System with Bang-Bang Controller. International Journal of Computer Techniques, 4(1).

[24] Lee, W. K., Shin, M. W., Kim, S. H., Jang, H., & Cho, M. H. (2013). The influence of humidity on the sliding friction of brake friction material. Wear, 302(1–2), 1397–1403. https://doi.org/10.1016/j.wear.2013.01.014

[25] Ducati Panigale V4 2021 Brochure. (2021). Ducati. https://assets.ctfassets.net/x7j9qwvpvr5s/3dttWusRKXI8VEuLlXcZ9I/0a28fca0e859c95569a04fad99f778b2/Brochure_MY21_Panigale_V4_ENG.pdf

[26] Brembo Brake Rotor 208B85911 for Ducati Panigale V4 R in Brake Rotors. (n.d.). CAPRIMOTO. Retrieved De cember 18, 2021, from https://www.carpimoto.com/en-BT/Bike_Ducati_Panigale-V4-R/Specific/Brand_Brembo/Brakes/Brake-Rotors/41487_208B85911-Brembo-SuperSport-Brake-Discs-for-Ducati-Panigale.htm

[27] Brembo Brake Rotor 68B407H1 for Ducati Panigale V4 R in Brake Rotors. (n.d.). CAPRIMOTO. Retrieved December 18, 2021, from http s://www.carpimoto.it/en-US/Bike_Ducati_Panigale-V4-R/Specific/Brand_Brembo/Brakes/Brake-Rotors/42247_68B407H1-Brembo-Serie-Oro-Brake-Rotor-68B407H1.htm

[28] SICOM T-DRIVE CARBON BRAKE DISCS PANIGALE 1299. (n.d.). [Photograph]. CARBON4US. https://www.carbon4us.com/en/carbono/12147-sicom-t-drive-carbon-brake-discs-panigale-1299.html

IMPLEMENTING PERIODIC REVIEW – VARIABLE ORDER QUANTITY SYSTEM IN INVENTORY MANAGEMENT: A CASE STUDY HEAVY EQUIPMENT COMPANIES, KUTAI BARAT

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ABSTRACT

One of the processes to minimize downtime unit is the availability of good spare parts. In this study, we will discuss how the process of developing reorder quantity procedures in order to get the availability of spare parts is quite good. in this study, the desired goal is the result of the researcher at 90%. The DMAIC method is used in this study to improve the existing processes in the reordering point. Periodic review with demand fluctuations, vendors holding stock, and inspection programs is an implementation carried out in the inventory process in order to get the availability of slow-moving spare parts, fast-moving spare parts, and spare parts that are monitored for damage. The results obtained are reordering quantity using Inspection which contributes 13% and casting using holding stock vendors based on customer brainstorming contributed 38% while the forgetfulness made by the distributor with periodic review modeling system contributed 43% so the accuracy of the prediction in January was 94% this support is greater than 2021, which is 88%, so there is an increase of 6% and a reduction in the delay time for repairs from 2021, the average order delay is 5.5 days to an order delay of 3.9 days.

CCS CONCEPTS

• **Periodic Review Inventory**; • **Inventory Management**; • **Lean Six Sigma**;

KEYWORDS

Availability spare parts, Inventory Management, Preventive Maintenance, Truck Product, DMAIC, Lean six sigma, Periodic Review Inventory

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1 INTRODUCTION

1.1 Background

PT United Tractors is a dealer of truck in Indonesia with 63 branches and sites Indonesian-wide. Availability parts especially trucks parts are more important for the support availability unit. It makes all customers focus on available parts, especially truck owners. The achievement of Truck product spare parts availability in 2021 with an average of only 88%, indicates that the available spare parts are not sufficient to back up customers in the West Kutai area.

The summarizing background of this research is as follows:

- Availability of spare Parts Truck Product at 2021 by 88%
- In 12 % parts no stock at distributor and must be indent to Belgium
- Delivery of spare parts from Belgium more than 20 days
- Customers will be lost production of 10.200 tons per unit per 20 Days
- Distributor can't prediction spare parts customer needed
- Customer buy some spare parts if the unit problem (Corrective Maintenance)
- Customers don't have an inspection program for backlog spare parts needed in the future
- This problem causes a decrease in customer satisfaction level
- It is feared that the customer will buy units from competitors in the future
- Customers hope distributor can fix this problem

1.2 Research Problems

The problem in this research is not available spare parts inventory and arrival delivery time then How does the company prepare the right spare parts according to customer's needs so customers don't have to wait too long to get these spare parts. The company is having difficulty in fulfilling customer demand on time due to the unavailability of the parts, particularly in urgent order cases.

1.3 Research Objectives

The objective of this research is to develop a system to optimize of availability spare parts truck with Preventive Maintenance especially Visual inspection for predictive spare parts needed and backlog.

1.4 Significance of Study

Learning from another paper, in fulfilling customers' orders, one of the goals of tactical supply chain planning is to satisfy the customers

in terms of delivery efficiency, delivery quantity accuracy, and on-time delivery. Our results enabled us to identify the worst and the best combinations of planning determinants. [1] *This tesis is significant* for reasons to evaluate the proposed method, which is using Predictive Maintenance, especially the visual inspection method, and its effect on the availability of spare parts inventory customers needed.

1.5 Research Questions

Question #1: How to develop an inventory that can support the customers?

Question #2: How is the improvement decrease lead time order customers?

1.6 Expected Outcome

The expected outcome is the improve this new system the lead time for ordering spare parts will be reduced.

1.7 Scope and Limitation

The scope of the study will focus on the specific increased availability of spare parts truck products with predictive maintenance especially visual inspection for predictive spare parts needed and backlog. The limitation of this research ignores the analysis of the existing order system and spare parts supply process.

2 LITERATURE REVIEW

2.1 Economic Order Quantity

Economic Order Quantity is one of the methods used in determining the optimal order quantity. The economic order quantity model is an inventory control technique that minimizes the total cost of ordering and holding. [2]

The Economic Order Quantity assumption is:

- The number of requests is known, constant, and independent
- The lead time i.e., the time between ordering and receiving the order is known and constant
- Receipt of inventory is instant and complete.
- No quantity discount available
- Variable costs are only costs for preparing or placing orders and holding the inventory within a certain time.
- Out of stock can be completely avoided if the order is placed on time.

The purpose of EOQ (Economic Order Quantity) is to determine the economic quantity per order so as to minimize the total cost of inventory.

The most significant costs are ordering costs and holding costs, while the inventory costs are constant. So, if ordering costs and holding costs are minimized, it will minimize total costs. As the quantity ordered increases, the number of orders will decrease. However, as the order quantity increases, the holding cost will increase as the average inventory count that needs attention becomes more [2]

The picture determined the Re-Order Quantity system. The process determines order quantity influenced by Cycle order, Lead time order, and safety stock. [3]

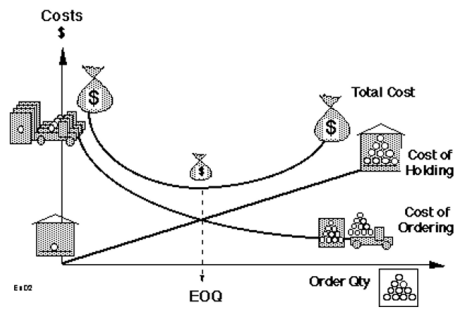

Figure 1: EOQ Model

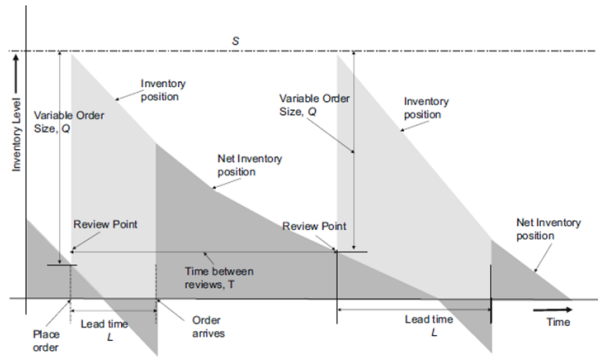

Figure 2: Re-Order Quantity system

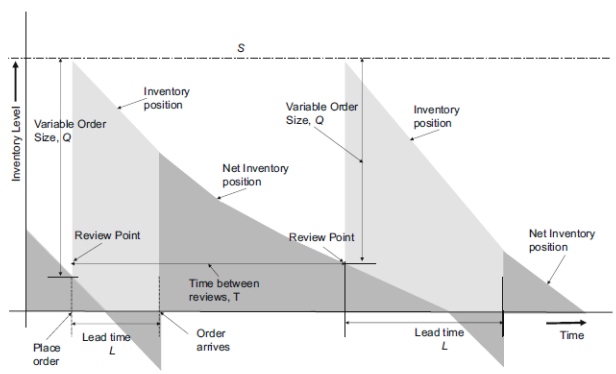

Fig. 2.3 Periodic review, order-up-to-level system

Table 2.1 Comparison of inventory control systems

Factor	Continuous review, fixed order quantity system	Continuous review, variable order quantity system	Periodic review, variable order quantity system
Monitoring of inventory level	Continuous	Continuous	Discrete points in time
Order size, Q	Fixed	Variable	Variable
Reorder level, s	Fixed	Fixed	Variable
Trigger for order	Event-based, when inventory level falls to s	Event-based, when inventory level falls to s	Time-based, at the review point, T
Time between stock reviews, T	Variable	Variable	Fixed
Size of safety stock, SS	Medium	Medium	High

Figure 3: Comparison of Inventory Control Method

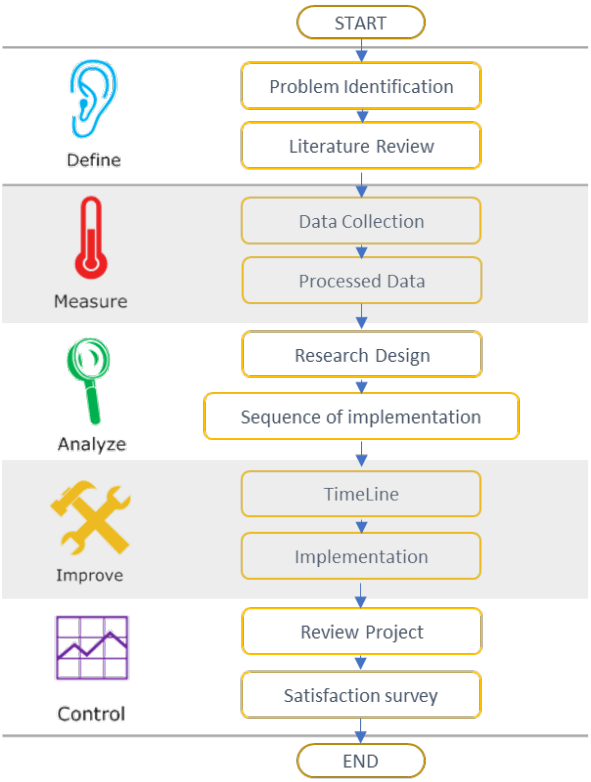

Figure 4: Methodology using DMAIC

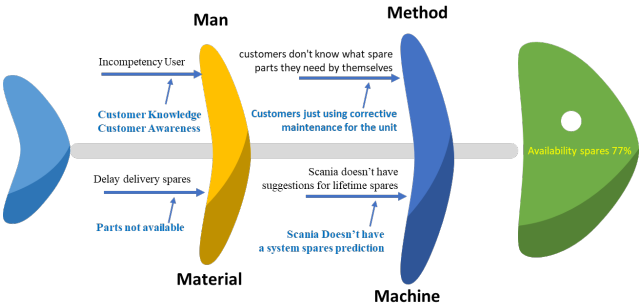

Figure 5: Ishikawa diagram

Considering the multi variance in inventory, comparation is needed for choosing the good method. [3]

3 METHODOLOGY

This research conducted a DMAIC framework for measuring the effectiveness of the improvement with lean six sigma. [4]

4 RESULT AND DISCUSSION

4.1 Define

In phase define tool Ishikawa diagram used for getting the rood cause in this research. Any 4 problems based on a focus group

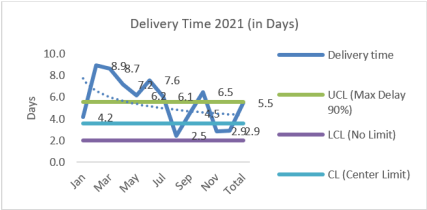

Figure 6: Delivery time 2021

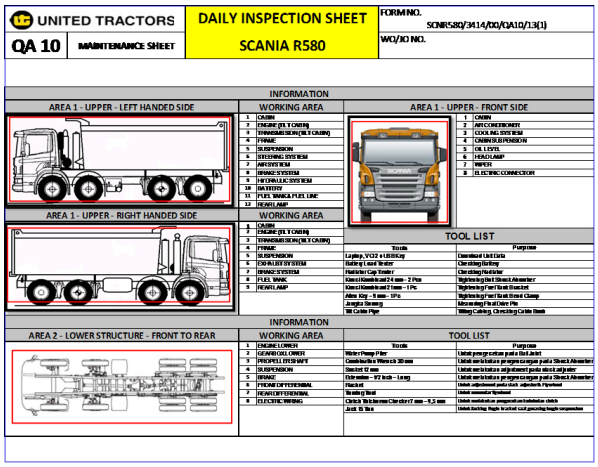

Figure 7: Daily Inspection Sheet

discussion with an expert an inventory at PT Unitectractors Tbk. [5]

4.2 Measure

The detail of the data item order, 480 items are not available and 3533 item is available.

Data availability will impact delivery time. Delivery time in 2021 averages 5,5 days for every order. This is an effect from 480 items are not available with a more 5 days delivery time.

Measuring data availability spares order and delivery time will get the result in lean six sigma with value defect per million order is 232.494 with range level 2 and 77% achievement. [6]

4.3 Analyze

Phase definition and phase measure make opportunities for improvement.

Tool Ishikawa diagram generated 4 problems in this research and using tools 5W1H get solution from the problem start from developing checklist inspection, develop standard procedure inspection, develop vendor held stock and reorder quantity using periodic review. [6]

4.4 Improve

4.4.1 *Developing checklist inspection [7].*

Table 1: Data Availability Spare Parts 2021

QTY 2021	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	sep	Oct	Nov	Des	Total
Available	272	209	344	290	203	248	250	492	370	392	463	0	3533
Not Available	55	48	77	59	29	46	35	62	46	67	57	0	480

Table 2: As is Performance

Process	CTQ	Target	Failure	Sample	Underspec	As is Performance
Forecasting Spares	Availability Spares 90%	3	D>5 day	3533	480	6∑:480/3533*1.000.000 6∑:135.861 Value DPMO 6∑: Level 2

Table 3: Define 5W1H

Category (What)	Root Cause (Why)	Solution (How)	Who	When	Where
Man	Incompetency User	Develop checklist inspection component Scania	Supervisor distributor	January 2022	Kutai Barat
Method	Customers just using corrective maintenance for the unit	Developing preventive maintenance system for inspection program	Supervisor distributor and Mechanic customer	January 2022	Kutai Barat
Machine	Scania Doesn't have a system spares prediction	Develop Vendor Held Stock based on Customers Experiences	Supervisor distributor and manager plan customer	January 2022	Kutai Barat
Material	Parts not available	Forecast spares using integrated fluctuation Demand	Parts analyst and supervisor	January 2022	Kutai Barat

Table 4: Result of implementation periodic review re order quantity [3]

No	Description	Example Constant demand	Example Variable demand
1	Quantity order month 1	4	7
2	Quantity order month 2	4	1
3	Quantity order month 3	4	2
4	Quantity order month 4	4	6
5	Total demand in 4 month	16	16
6	Total Average Demand per month	4	4
7	Deviation demand	0	2,5
8	Deviation lead time (same lead time)	0	0
9	Value (z)	80%	80%
10	Cycle order (Co) (Per Month)	4	4
11	Lead time order (Lt) - 20 Days (0,66 month)	2,6	2,6
12	Safety stock (Ss)	0	3,4
13	Re-order Quantity	6,6	10

4.4.2 4.4.2 Develop standard procedure inspection. In this research make a procedure inspection program for getting the opportunities of spares needed from customers earlier before spares broken. Distributors will be ordered early for stock with expectations if spares broke and customers needed the spares, spares will be ready to stock at the warehouse distributor early. [4]

Prosedur will impact data spares needed from customers.

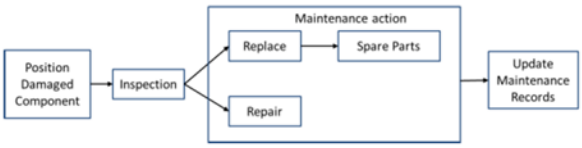

Figure 8: Flow Inspection

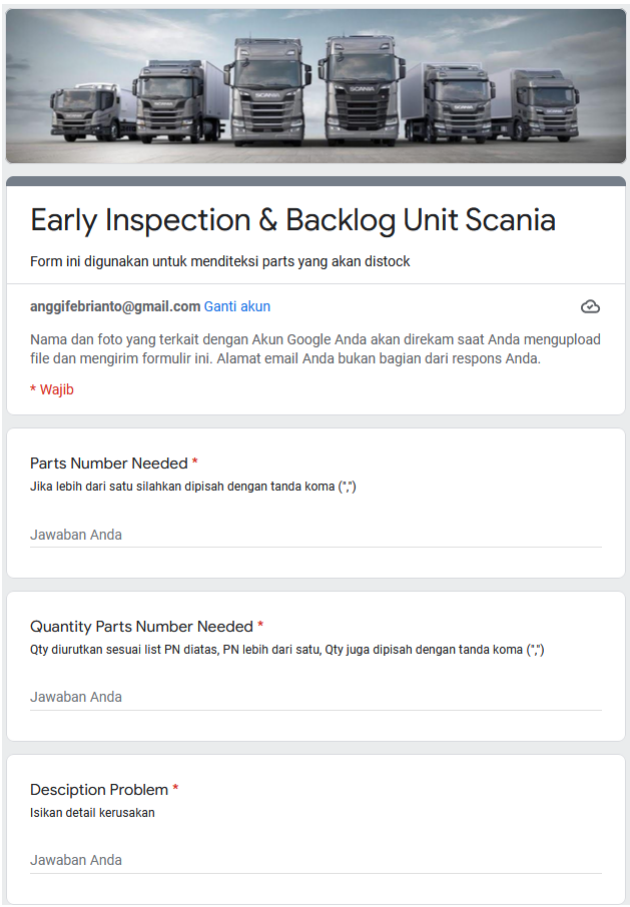

Figure 9: Input Data to Google Form

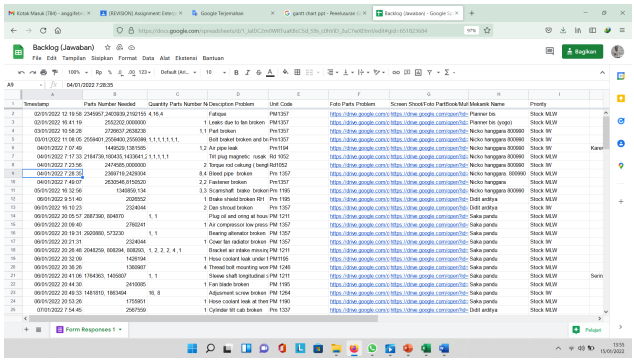

Figure 10: Download data from Google Form

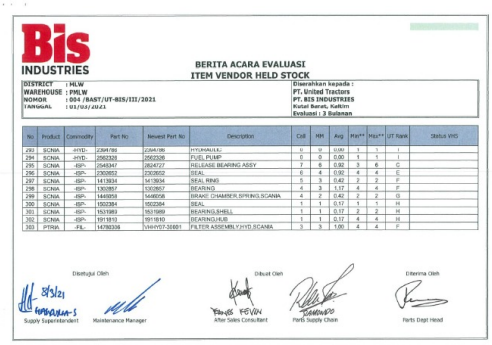

Figure 11: Implementation Vendor Held Stock

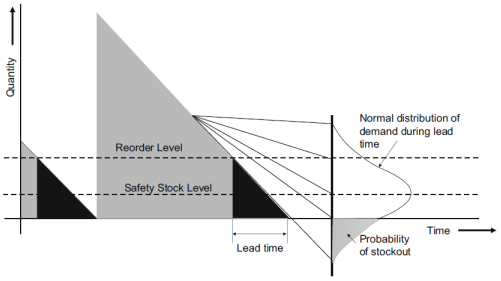

Fig. 6.5 Demand during lead time is normally distributed

Figure 12: Probability of Stockout

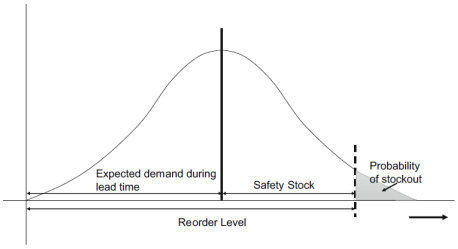

Fig. 6.6 Safety stock and probability of stockout

Figure 13: Statistical of Probability of Stockout

4.4.3 Develop vendor held stock (VHS). Vendor-held stock is one of a method for getting information from customers about what customers need for spares in the further. Distributors and customers make focus group discussions using the experiences of customers handling the units. [4]

4.4.4 reorder quantity using periodic review. Inventory control will be involved kind of item spares. High variable demand and variable lead time will impact reorder point quantity. in this research will using continuous review method with variable order quantity [3]

This picture determines of the relationship between the reorder level and safety stock for desired service level. The function of

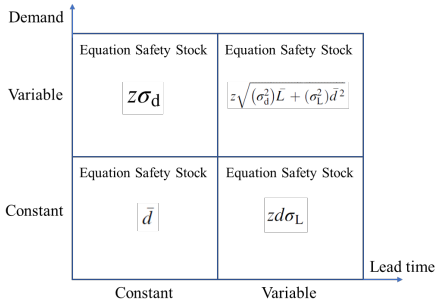

Figure 14: Comparison Equation Safety Stock

$$\mathrm{CI} = \frac{Q}{2}$$

Figure 15: for single item and for multi-item using average demand

$$\mathrm{PI} = DL$$

Figure 16: for single item and for multi-item using Avg. demand * Avg. lead time

$$\mathrm{SS} = z\sqrt{(\sigma_d^2)\bar{L} + (\sigma_L^2)\bar{d}^2}$$

Figure 17: Equation Safety Stock

Inventory determines such as average demand based on cycle inventory quantity by lead time based on pipeline inventory safety stock based on continuous review inventory. [2]

Theoretical of the fluctuation inventory determines Equation Reorder Point :

ROP = Avg.Demand + Qty by Leadtime + SafetStock

From the data above, high fluctuation demand will impact to increase safety stock and will increase the reorder point quantity.

4.5 Control

Data after improvement in 2022 availability increase 6% from 88% in 2021 to 94% in 2022. Impact to lean six sigma from level 2 increase to level 3 linier with the increasing availability.

Increasing availability also impact to delivery time from average 5,5 days in 2021 to 3,9 days in 2022.

In order for the project to always run well, it is necessary to carry out the sustainability of the project, including:

1. Weekly meeting review achievement customer dan distributor
2. Review the project every 2 month
3. Review the problem-solving process in the project
4. Assessment process documentation
5. Genba process inspection and assessment behavior
6. Discuss the next project
7. Rewarding

$$\mathrm{ROP} = \bar{d} + \bar{d}\bar{L} + z\sqrt{(\sigma_d^2)\bar{L} + (\sigma_L^2)\bar{d}^2}$$

Figure 18: Equation Re-Order Point

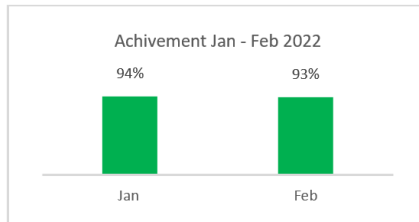

Figure 19: Achivement Availability Spares 2022

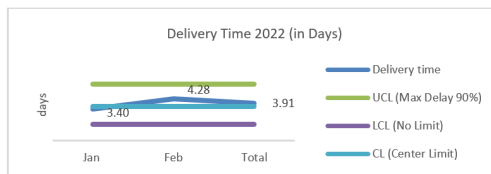

Figure 20: Achivement Dalivery Time 2022

5 CONCLUSION

5.1 Conclusion

In this research, the process that has been carried out is reorder quantity modeling from the results of the improvement process, it was found that Short term reorder quantity using inspection contributed 13% and for casting using held stock vendors based on customer brainstorming contributed 38% while forgetting carried out by distributor with the Economic modeling system contributed 43% so that predictable accuracy in January is 94% this achievement is greater than in 2021 which is 88% so that there is an increase of 6% and reduces the delay time to repair from the 2021 average of 5.5 days delay order becomes 3.9 days delay order.

5.2 Recommendation

1. Advice to continue research with a comparative lifetime part of the unit.
2. Advice to continue research Using another method of reordering quantity inventory parts.
3. Advice to continue research using data analytics with machine learning
4. Develop system communication for transfer data between customer and distributor
5. Develop dashboard real-time achievement for monitoring ordering spares process

ACKNOWLEDGMENTS

This research only focuses on inventory spare parts truck products and case study in site kutai Barat.

Table 5: Achivement Availability Spares 2022

Qty 2022	Jan	Feb
Available	221	289
Not Available	14	21

REFERENCES

[1] [1] U. Okongwu, M. Lauras, J. François, and J. C. Deschamps, "Impact of the integration of tactical supply chain planning determinants on performance," *Journal of Manufacturing Systems*, vol. 38, pp. 181–194, 2016, doi: 10.1016/j.jmsy.2014.10.003.

[2] [2] S. Rahayu Pardede and I. Vanany, "Analysis and control for heavy equipment spareparts inventory in nikel mining industry," *IPTEK Journal of Proceedings Series* , vol. 6, pp. 1–6, 2020.

[3] [3] D. Shenoy and R. Rosas, *Problems and solutions in inventory management*. Springer International Publishing, 2017. doi: 10.1007/978-3-319-65696-0.

[4] [4] A. Romanov, M. Herson, and S. M. Program, "Analysis and Reduction of Excess Inventory at a Heavy Equipment Manufacturing Facility," 2013.

[5] [5] Y. Triuntoro and F. W. Abdul, "Perbaikan Warehouse Business Process Dengan Metode Lean Six Sigma Di PT. XYZ," 2021. [Online]. Available: http://ojs.stiami.ac.id

[6] [6] M. Taufiqurrahman, "Pendekatan Design For Six Sigma Pada Perancangan Sistem Informasi Preventive Maintenance Untuk Support Facilities Perangkat BTS (Base Transceiver Station)," *ELKHA*, vol. 7, no. 2, pp. 26–32, Oct. 2015.

[7] [7] Scania, *Scania P, G, R, T series Workshop manual - Identification of materials*. Swiss: https://truckmanualshub.com/scania-trucks-service-repair-manuals-pdf/, 2021.

Sustainable Supply Chain Framework Design in Indonesian Palm Oil Industry with IoT Integration

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ABSTRACT

Palm Oil Production has increased rapidly as the demand has also grown in recent years. The production of global palm oil mostly comes from Southeast Asia and South America. However, palm oil production also gives several negative impacts on society and the environment. Palm oil's negative impact has been a significant issue in most palm oil producers in the world, especially in Indonesia, which contributed the most significant portion of the world's palm oil production. Therefore, a sustainable supply chain management model for the palm oil industry needs to be conducted. The supply chain needs to consider social factors and the environment as crucial factors to create sustainability. This paper proposes a framework for a sustainable supply chain (SSC) with the integration of the Internet of Things (IoT) to meet company goals, achieve customer requirements, and also sustainability for the company, societies, and environment. The method for conducting the study is by comprehensive literature review. The most important finding is IoT that present in the study becomes an enabler to give visibility and transparency for the entire SSC as enhancement of technological use might give a significant benefit.

CCS CONCEPTS

• **General and reference** → Cross-computing tools and techniques; Design; • **Social and professional topics** → Professional topics; Computing industry; Sustainability.

KEYWORDS

Sustainable Supply Chain Management (SSCM), Internet of Things (IoT), Palm Oil Industry, Framework Design

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1 INTRODUCTION

Nowadays, the production of palm oil has been overgrown. The usage of palm oil mostly for food, biodiesel, and commodity products, and the impact on the environment become large with the expansion of palm oil plantations [1]. This issue has been a problem in the palm oil producer countries for years especially in Indonesia as the expansion of plantations number, the number of productions, and the rise of demand creates complexity across the entire supply chain network. Sustainability is needed to answer the growing issue, especially in the sector of the palm oil industry. Three main factors in achieving sustainability are economic, social, and environmental. The purpose of each factor in sustainability is different. Economic target is based on the financial and non-financial factors, Environment target is based on the positive and negative impacts on the environment, and social target is based on the reduction of harm/problems that might occur in the communities [2]. As the business expands, from an economic perspective, oil palm producers gain much profit because of the increment of demand and number of sales. However, practically, the current concern occurs about the business ethics where the expansion of palm oil plantations creates massive damage to the environment, especially regarding deforestation and fragmentation causing the rise of C02 emissions and freshwater pollution [1] [3]. The cause of environmental damage is also affecting the communities [1].

The implementation and practices of sustainability face difficulties from several factors such as economic, political, technologies, innovation, and infrastructure to support the supply chain [4]. However, the growing concern about sustainability is making an urgency for solving the problem that occurs growing in the palm oil industry sector. A framework is needed for creating SSC to give better conditions regarding the economic, environmental, and social results of palm oil industry sectors.

The supply chain itself has become a crucial factor to achieve competitive advantages in various industries [5]. The operations of the supply chain have a significant influence on the cost and profit of a company. The key drivers of the supply chain that enhance the operation within the company are material, logistics, and operations [6]. Supply chain management also evolving, and in the recent past, the terminology of (SSC) is often discussed. A sustainable supply chain combined the supply chain theory with consideration of the sustainable aspect, where the definition of sustainable might be different in each literature [6]. By this definition, SSC became very suitable for the Palm Oil Industry issue. In this paper, environmental and social become the focus of sustainable terms.

The SSC framework also considers the issue of Industry 4.0 to adapt to the dynamics and uncertainty, especially for the global

demand. The reason why the framework needs to be integrated with the Internet of Things (IoT) is to give additional features to maintain and control sustainability such as vertical networking and integration to the entire value chain [7] [8]. Also, give features for data acquisition and big data. The data is used for supply chain analytics for predicting the future supply, demand, and risk regarding the palm oil industry itself [9].

2 LITERATURE REVIEW

The literature review will be divided into four parts. The first part is discussing the condition of palm oil industries in Indonesia. The second part is about the Sustainable Supply Chain Management (SSCM) frameworks that have been developed by several authors from previous research; the third part is about the supply chain in palm oil industries, and the fourth is about the impact of Industry 4.0 to supply chain management.

2.1 Indonesian Palm Oil Industry

Palm oil industries in Indonesia have been multiplying in recent years due to the growing demand for palm oil domestically and globally. This issue leads to the expansion of palm plantations in Indonesia. Sharma et al. (2019) defined the conversion of forests into palm plantations resulted in the reduction of ecosystem functions [1] [10].

On the other hand, oil palm plantations also improve the economic growth of the local communities [10]. Contrary, Santika, et al. (2019) defined in their studies that oil palm industries are causing socioeconomic disparity and environmental costs while only a small portion of elites take the largest share of economic benefits [11]. Even with this condition, palm oil industries giving a significant contribution to Indonesian export revenue.

The role of government in the industries is essential, especially regarding policy to create sustainable palm oil for Indonesian [12]. Palm oil also can be used as renewable and biomass energy. However, the sustainability of palm oil-based biomass energy in Indonesia is still very low and needs to be developed [13].

2.2 Supply Chain in Palm Oil Industries

The supply chain in the palm oil industry is quite complicated. The end product of palm oil industries not only consumable products but also could be biomass energy. Jensen et al [14] developed a simplified palm oil supply chain. The supply chain network in palm oil industries mostly started with the plantation or some literature using "farm" as a similar term. Then the raw material, which is the palm fruits, will go to the milling process. After the milling process is the refinery process, then the manufacturing process. After the manufacturing processes, the end product will be sent to the retailer [14]. However, the schematic regarding the palm oil supply chain has not included the biomass energy / renewable energy product that can result from the waste of palm oil production.

Additional literature regarding the supply chain scheme of biomass energy produces by palm oil. There are two previous studies regarding the biomass energy supply chain and the scheme of biomass energy supply chain. The supply chain started from the plantation or farms, second phase is the raw material (palm fruits) will be treated in the pretreatment facilities, and then the result from the treatment will deliver to the bio-refineries process resulting in the end product to be used for the customer [15] [16].

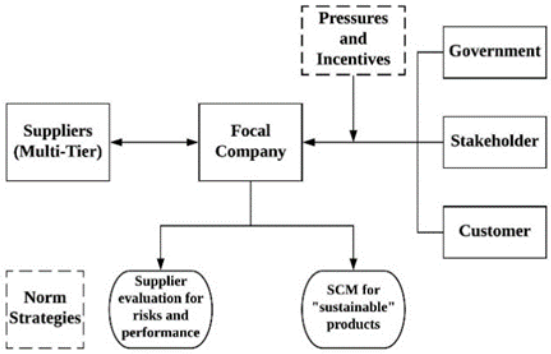

Figure 1: 1997 Triggers for Sustainable Supply Chain Management [14]

2.3 Sustainable Supply Chain Management (SSCM)

Seuring and Müller [14] stated that the triggered SSCM incentives from all stakeholders such as customers and the government. Figure 1 is showing the triggers for sustainable supply chain management The government has an essential role in triggering SSCM applications. Meanwhile, communication becomes the most significant barrier to SSCM implementation. The increased supply chain complexity resulting in communication becomes the most critical matter. Inter-organizational communication can improve the performance and risk management of the company. However, there are several other enablers, such as monitoring and integration of sustainability and company policy [17].

Carter and Rogers [18] created a concept of SSCM that was validated by various large German and US enterprises. The validation method was by interviewing the supply chain managers. SSCM concept was developed by Carter and Rogers based on The Triple Bottom Line, which consists of environmental performance, environmental performance, and economic performance. The study reveals that SSCM is critical for long-term economic success. SSCM also considers the element of risk, that is the reason risk management becomes essential [18].

Carter and Rogers also stated that transparency in SSCM creates stakeholder engagement and transparency is also able to improve vertical and horizontal coordination. vertical coordination might enhance the performance based on an economic perspective under uncertainty. The study also gives a practical implication regarding the enhancement of environmental and social strength.

2.4 Impact of Industry 4.0 on Supply Chain Management

The impact of Industry 4.0 on to supply Chain might result in opportunities and threats. Tjahjono et al. [7] defined the opportunities and threats of Industries 4.0 with company supply chain processes. The supply chain processes examined are procurement, warehouse,

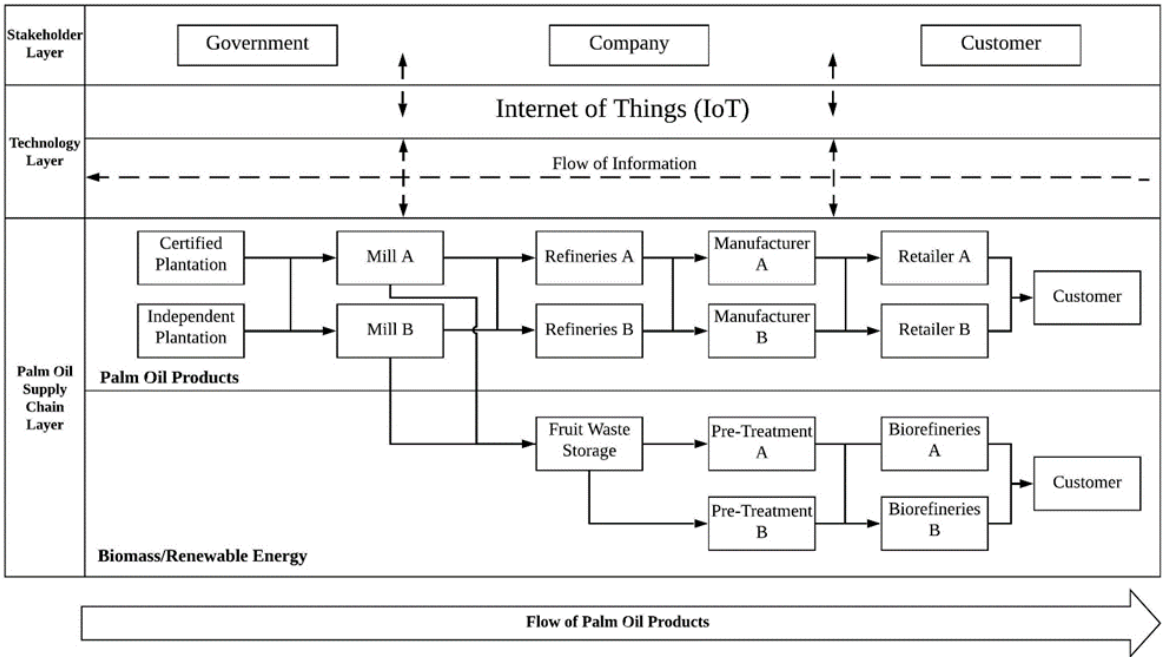

Figure 2: Proposed Sustainable Supply Chain Framework for Palm Oil Industry with IoT Integration

logistics transport, and fulfillment. The research shows that Industry 4.0 technologies such as virtual and augmented realities, 3D-Printing, and simulation resulted in opportunities. However, big data analytics, cloud technology, cybersecurity, the IoT, miniaturization of electronics, M2M, and BI could have possibilities to be opportunities or threats for the company. However, the most important thing is that the benefit of Industry 4.0 technologies to the supply chain might give productivity, efficiency, and flexibility. Those benefits give the ability companies to meet customer demand and create value for products and services [7].

However, integrating Industry 4.0 into the supply chain, some challenges might occur. There are several challenges defined by Luthra and Mangla [19] such as poor data quality, lack of integration of technology platforms, lack of government support, lack of government policy, legal issues, lack of industry 4.0 knowledge, etc. [19]. These challenges become the reason why the integration of Industry 4.0 into the supply chain is not an easy matter. However, it needs involvement from all stakeholders, especially the government, customers, and the company itself.

3 PROPOSED FRAMEWORK

This section is discussing the proposed conceptual framework for a sustainable supply chain in Indonesian palm oil industries in Indonesia with IoT Integration.

Palm oil in Indonesia contributes a large portion of exported commodities and makes substantial revenue for Indonesia. Besides, Indonesia has been the largest producer of palm oil around the globe. Complexity also occurs when there is too high a demand. However, sustainability regarding the industry from the perspective of the environment and society is not well developing. This led to negative impacts on the environment such as deforestation, a rise in CO2 emission, and polluted water. The negative impact of the environment also affects social problems, such as poverty, poor living environment, and health issue. This is the main reason why the Indonesian palm oil industry become the object of the development of an SSC framework. The first way that can be taken as a solution for the growing issue is through accessing sustainability aspects. Integrating the sustainability aspect into SCM can be a possible way to reduce the negative impact on society and the environment while economic performance still can be maintained. palm oil industries have taken as the case to develop the SSC framework because of the urgency regarding the environment and social performance resulting from the palm oil industries themselves, and the urgency has been investigated in several literature studies as discussed in the literature review of this paper.

Figure 2 is showing the framework of SSC for the palm oil industry with IoT integration. The integration of the SSC framework of palm oil industries in Indonesia with the IoT is not without reason. Transparency and communication are essential in a sustainable supply chain. Transparency and communication become vital factors in integrating all stakeholders across the entire supply chain. The use of IoT designed to become an enabler for transparency and communication across the supply chain can be integrated and also give accuracy regarding the information flow based on data reliability and time. Product status such as temperature, volume, quality, and other product specifications also can be stored and accessed. There are three layers in the sustainable supply chain framework.

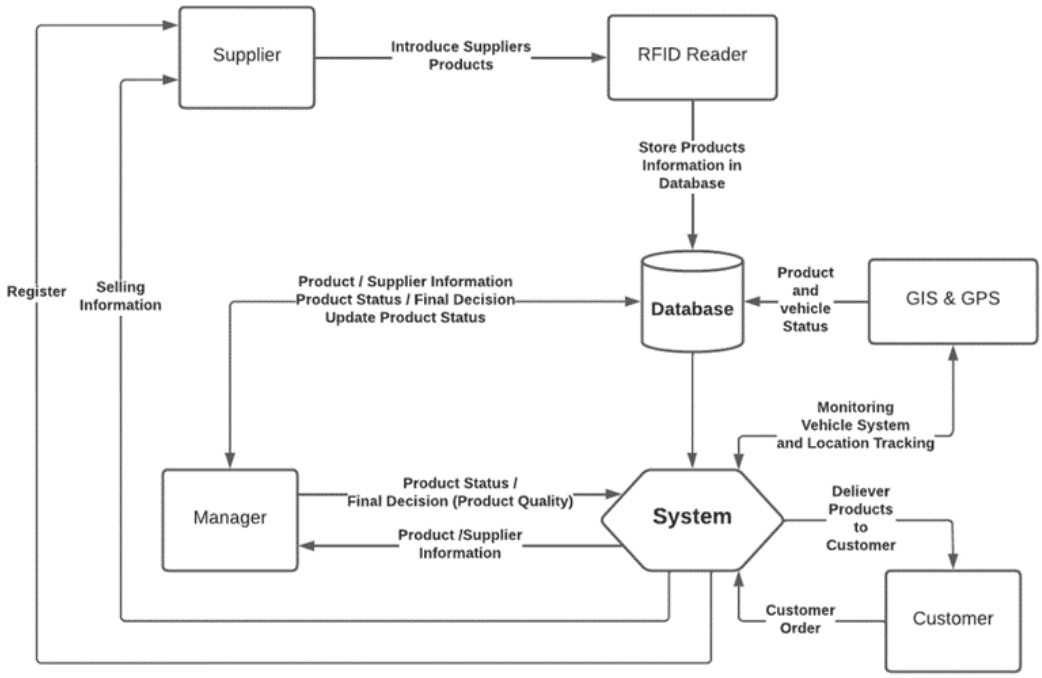

Figure 3: Detailed Technology Layer (IoT) in Proposed Sustainable Supply Chain Framework

- Palm Oil Supply Chain Layer: This layer is the simplified supply chain process for palm oil. The products consist of palm oil products and biomass energy.
- Technology Layer: This layer is consisting of IoT. The purpose is to bridge the supply chain layer and stakeholder layer. As well the most important thing is the flow of information throughout the entire palm oil supply chain.
- Stakeholder Layer: This layer consists of stakeholders in the palm oil supply chain. The stakeholder defined are government, company, and customer.

Figure 3 is showing the Detailed Technology Layer in the proposed Sustainable Supply Chain Framework. Abdel-Basset et al [20] proposed a framework for building smart, secure, and efficient systems by utilizing technology in IoT. Sofianti et al [21] designed a computer-integrated shopfloor which is part of the supply chain process intending to enable product status control in a real-time situation. Fusing the two concepts resulted in the fundamental technology layer proposed in Figure 2.

The framework constructed a system for the supplier, manager, and customer. RFID (Radio Frequency Identification), a technology of IoT become the main body of data collection across the entire supply chain network. RFID is used to scan the palm oil product at each stage of the supply chain. The data will be uploaded to the database and the detail can be accessed by the manager. The manager will assess the quality, volume, and other product requirements to decide whether to purchase the product or not. The product details also can be shared across the entire supply chain network and layers. The final stage is to deliver the products to the customer. Customer orders can be collected by using smartphone technologies. The delivery and distribution process required a smart transportation system supported by GPS (Global Positioning System). GIS (Geographic Information System). To track vehicle location and product safety, sensors technology is also installed.

4 EXPECTED IMPACT

The framework was designed from Indonesia's palm oil industry sector. A conceptual framework from previous research regarding the palm oil supply chain was also conducted and adjusted with the Indonesian palm oil supply chain network. The scope of this study consists only of the conceptual framework development that occurs from previous research and literature reviews.

There are two usages of technologies that considered can achieve sustainability in the framework:

- *Usage of Biomass Energy*: The framework is considering the waste of palm oil production such as palm kernel shells, which can be converted into biomass energy. The usage of biomass energy can be widely used, such as in power plants for electricity. The result of using biomass energy is giving better performance regarding the environmental issue. Biomass and renewable energy can have fewer emissions than conventional energy sources such as coal.
- *Usage of Internet of Things (IoT) Integration*: Integration of IoT is designed to enhance supply chain productivity and

efficiency. Therefore, the objective is to boost economic performance by reducing costs and increasing profit. Real-time monitoring or control and transparency across the supply chain network can be achieved by using the Internet of Things (IoT). The government needs to perform control functions across the entire supply chain. This might result in the government's ability to create policy based on the objectives of sustainability not only considering the factor of economics but also the environment and society.

Several benefits can be achieved by implementing the framework.

- *Enhance Data Acquisition*: Data acquisition also can be obtained by implementing IoT. This function can help the company to predict the supply and demand in the future and can be used as an enabler to achieve long-term economic success.
- *Real-Time Control:* IoT function is also for real-time control across the supply chain network. Control accuracy can be improved as the use is for assessing the risk that might occur in the supply chain network.
- *Integrated Communication*: IoT also can integrate the communication between stakeholders across the entire supply chain Because there is complexity in the palm oil industry supply chain. This not only improves communication but also reduces the flow of information. Therefore, communication efficiency can be obtained.
- *Transparency and Traceability*: IoT can give transparency and traceability across the supply chain network regarding processes and data. However, some literature still argues instead transparency is an opportunity or threat because some parties still have security concerns regarding transparency as they also need to protect their interest.
- *Government Engagement*: Government engagement in this framework is considered an opportunity. Still, the government holds the position as the most potent figure among all stakeholders. The role of government in the supply chain mostly regarding the policymaker. Especially about palm oil plantation expansions. As long as the government could be a counterweight between all parties in the supply chain, sustainability can become possible to be achieved. The government also can issue standard certification regarding legal palm oil industries — this help to avoid illegal producers that might cause a loss in the environment and social factors.
- *Renewable/Biomass Energy*; Palm oil industries production creates various types of waste. However, the waste can be used as biomass and renewable energy. The usage of this new energy could give benefit the environment and social performance.

5 CONCLUSION

Indonesia has become one of the global palm oil producers. The palm oil supply chain also has a complex system. Maintaining the sustainability of the palm oil supply chain is essential to achieving a competitive advantage through vertical integration between processes and stakeholders across the chain. The result can be cost efficiency and enhanced profit. However, sustainability cannot be measured only by the economic factor or profit within the business. Sustainability is also considered an environmental and social factor.

The SSC of the palm oil industry can be achieved by integrating technologies into it. One of the technologies that can be integrated into the IoT and also the adoption of renewable energy. The integration of technology, primarily Industry 4.0 into the supply chain, can give many benefits such as transparency, traceability, real-time control, data acquisition, and the essential thing is government engagement for control. With this benefit, sustainability can be achieved not only from the economic but also from the environmental and social aspects. Biomass or renewable energy is also considered in the sustainable supply chain to give benefits to the economic, environmental, and also social.

The future research should be the implementation testing of the framework to the palm oil industries or interviews regarding the framework also can be done to have expert judgment. Analysis of performance also can be conducted from the framework. The limitation of this research is that the framework has not been implemented; the expected result of the framework from this paper still needs to be assessed more.

REFERENCES

[1] M. G. Rulli, S. Gasirati, J. Dell'Angelo, K. F. Davis, G. Passera og P. D'odorico, Interdependencies and telecoupling of oil palm expansion at the expense of Indonesian rainforest, Renewable and Sustainable Energy Reviews, vol. 105, pp. 499-512, 2019.

[2] N. Oelze, M. Brandenburg, C. Jansen og R. Warasthe, Applying Sustainable Supply Chain Management Frameworks to Two Germans Case Study, Internation Federation of Automatic Control (IFAC), vol 251-30, pp. 293 - 296, 2018.

[3] G. C. Schoneveld, S. V. D. Haar, D. Ekowati, A. Adrianto, H. Komarudin, B. Okarda, I. Jelsma og P. Pacheco, certification, good agricultural practice, and smallholder heterogeneity: Differenciated pathways for resolving compliance gaps in the Indonesian oil palm sector, Global Environmental Change, vol. 57, p. 101933, 2019.

[4] A. M. Gomez, F. A. Gonzalez og A. Luque, A holonic framework for managing sustainable supply chain in emerging economies with smart connected metabolism, Resources, Conservation & Recycling, vol. 141, pp. 219-232, 2019.

[5] A. Qorri, Z. Mujkic og A. Kraswalski, A Conceptual Framework for measuring sustainability performance of supply chain, Journal of Cleaner Production, vol. 189, pp. 570-584, 2018.

[6] E. Manavalan og K. Jayakrishna, A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirement, Computers & Industrial Engineering,vol. 127, pp. 925-953, 2019.

[7] B. Tjahjono, C. Esplugues, E. Ares og G. Pelaez, What does Industry 4.0 mean to Supply Chain?, Procedia Manufacturing, vol. 13, pp. 1175-1182, 2017.

[8] S. P. Singh, R. K. Singh, A. Gunasekaran og P. Ghadimi, Supply Chain Management, Industry 4.0, and the Circular Economy, Resources, Conservation & Recycling, vol. 142, pp. 281-282, 2019.

[9] S. Zhu, J. Song, B. J. Hazen, K. Lee og C. Cegielski, How supply chain analytics enables operational supply chain transparency, International Journal of Physical Distribution & Logistics Management, vol. 48, nr. 1, pp. 47-68, 2018.

[10] S. K. Sharma, H. Baral, Y. Manonier, B. Okarda, H. Komarudin, H. Purnomo og P. Pacheco, Ecosystem services under future oil palm expansion scenarios in West Kalimantan, Indonesia, Ecosystem Services, vol. 39, p. 100978, 2019.

[11] T. Santika, K. A. Wilson, S. Budiharta, E. A. Law, T. M. Poh, M. Ancrenaz, M. J. Struebig og E. Meijaard, Does oil palm agriculture help alleviate poverty? A multidimensional counterfactual assessment of oil palm development in Indonesia, World Development, vol. 120, pp. 105-117, 2019.

[12] A. J. Astari og J. C. Lovett, Does the rise of transnational governance 'hollow-out' the state? Discourse analysis of the mandatory Indonesian sustainable palm oil policy, World Development, vol. 117, pp. 1-12, 2019.

[13] P. Papilo, M. E. Hambali og I. S. Sitanggang, Sustainability index assessment of palm oil-based bioenergy in Indonesia, Journal of Cleaner Production, vol. 196, pp. 808-820, 2018.

[14] P. D. Jensen, L. Whicker og P. Deutz, Sustainable Palm Oil Supply Chains: Complexity, Custody and Contention, Proceedings of 21st Logistics Research Network Annual Conference, 2016.

[15] D. H. Nguyen og H. Chen, Supplier selection and operation planning in biomass supply chains with supply uncertainty, Computer and Chemical Engineering,

vol. 118, pp. 103-117, 2018.
[16] S. M. Zahraee, S. R. Golroudbary, N. Shiwakoti, A. Kraswalski og P. Stasinopoulos, An investigation of environmental sustainability of palm biomass supply chains via dynamic simulation modeling: A case study of Malaysia, Journal of Cleaner Production, vol. 237, p. 117730, 2019.
[17] S. Seuring og M. Müller, From a literature review to a conceptual framework for sustainable supply chain management, Journal of Cleaner Production, vol. 16, pp. 1699-1710, 2008.
[18] C. Carter og D. Rogers, A framework of sustainable supply chain management: moving toward new theory, International Journal of Physical Distribution & Logistics Management, vol. 38, pp. 360-387, 2008.
[19] S. Luthra og S. K. Mangla, Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies, Process Safety and Environmental Protection, vol. 117, pp. 168-179, 2018.
[20] M. Abdel-Basset, G. Manogaran, and M. Mohamed, "Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems," Futur. Gener. Comput. Syst., vol. 86, pp. 614–628, 2018, doi: 10.1016/j.future.2018.04.051.
[21] T. D. Sofianti *et al.*, "Design of computer integrated assembly line," ACM Int. Conf. Proceeding Ser., pp. 144–148, 2018, doi: 10.1145/3284516.3284526.

Komatsu's Spare-parts Service Level and Day of Inventory Improvement for PT. MTN

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ABSTRACT

PT UTB faced problem of its fluctuating demand of spare parts that make its inventory very high. The purpose of this research to increase the service level to meet its target at 80% and reducing days of inventory to reach below 50 days. The method used in this research used five whys analysis to find the root cause of the problem. Then, conducting forecasting using moving average method through several time series. Economic Order Quantity (EOQ) also was calculated to identify the best method to achieve the research objectives. The Human Factor Analysis and Classification System (HFACS) method is used to analyze the causes of human error in the ordering process based on human error and the role of the organization in fulfilling performance, as well as to obtain recommendations for prevention. Task analysis also was used to analyze the process of ordering spare part to improve it lead-time. The results showed that the moving average method and economic order quantity (EOQ) was able to make the stock more effective and efficient and increasing service levels and decreasing days of inventory (DOI). The Vendor held stock (VHS) system is used as a solution in improving service level measurements and increasing the speed of supply of spare parts to PT. MTN.

CCS CONCEPTS

• **Information systems**; • **Data management system**; • **Data mining**;

KEYWORDS

Days of inventory, Economic order quantity, Human Factors Analysis and Classification System (HFACS), Service level, Task Analysis

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1 INTRODUCTION

The need for spare parts for heavy equipment is especially needed by PT. MTN to carry out the maintenance process for its heavy equipment. PT. UTB, as a distributor of heavy equipment fulfils the demand for heavy equipment spare parts for PT. MTN, has facing several problems. First, its availability performance of Komatsu spare parts to meet PT. MTN's demand was only achieved at 74%, below the 80% of target performance. Second, Komatsu spare parts stock turnover have days of inventory (DOI) level at 86 days, compared to the target below 50 days. Days of inventory or DOI is the amount of inventory or stock of goods compared to the average sales in a certain period. By calculating DOI accurately, it will make it easier for management to make decisions on the total inventory value (Maserih, 2017). Meanwhile, according to Trautrims et al. (2009) said that the service level for consumers is realized by product availability as an indicator of the performance of the entire supply chain, as shown in equation 1).

$$\text{Service Level} = \frac{\text{Available demand}}{\text{All Demand}} \times 100\% \tag{1}$$

$$DOI = \frac{Stockamount}{AverageCOGSatagivenperiod} * 30days \tag{2}$$

From historical transaction data, the classification based on the speed of movement of each item can be done using FSN Analysis (Brindha, 2014), namely fast moving, slow moving and non-moving parts, as shown in Table 1.

2 RESEARCH METHODOLOGY

This research used the define-measure-analyze-improve-control or DMAIC methodology, as shown in Figure 3. This methodology is as data-driven quality strategy that normally used to improve quality. This methodology also useful for continual improvement and cost

Figure 1: Service Level Performance in The Year 2021

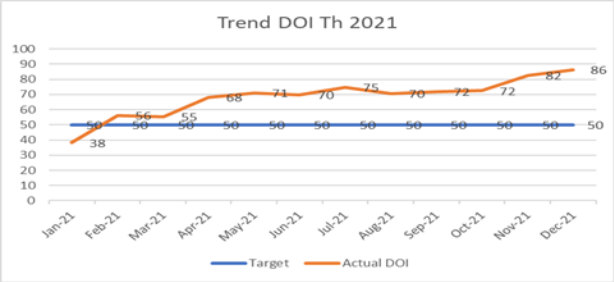

Figure 2: Days of Inventory in The Year 2021

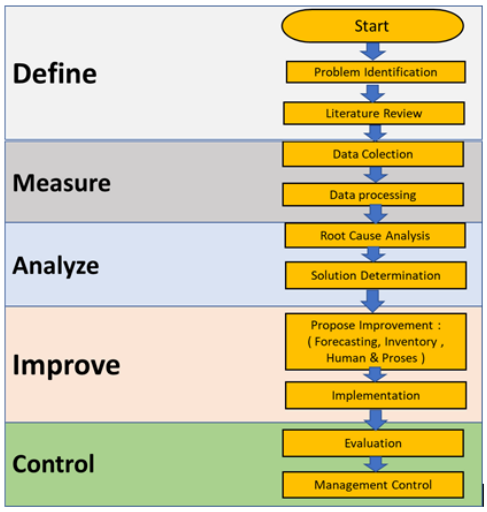

Figure 3: Research Methodology DMAIC

reduction by cutting output variations to a level that is appropriate for the organization. (Mustapha Roslina at el, 2016).

Data was collected based on historical evidence of spare parts transactions in year 2021. These data then were plot into graphic for the best presentation of the current situation with concern of service level performance and days of inventory.

These data then would be analyzed using five whys methodology to find the root cause of the problems. The five whys method is a simple and effective way to get preventive action from the root cause so that the problem does not recur (Mind Tools Ltd, 2019).

The forecasting method, using moving average model, was then used to make historical actual demand data in year 2021 into future forecast values. According to Chopra (2007) stated that when demand is neither seasonal nor trending, the moving average method is appropriate to use. So, the moving average is useful if we can assume that market demand will tend to be stable over time (Jay Heizer, Barry Render, Chuck Munson, 2010).

The human factors analysis and classification system or HFACS method was used to further analyze the causes of process errors. HFACS is based on James Reason's Swiss cheese model (Bridger, 2003).

Hierarchical Task Analysis (HTA) then was used to classify the improved task should be carried out in process order. According to

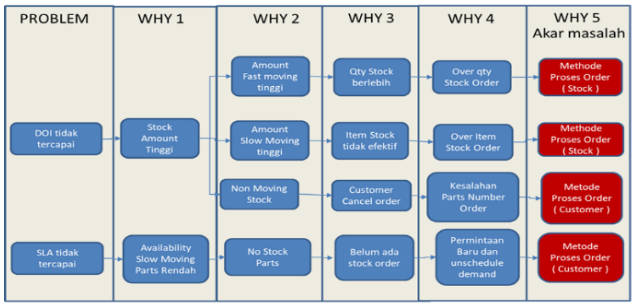

Figure 4: Five Whys to Find Root Cause of Low Service Level and High Days of Inventory

Jhon Annett (2000), task analysis can analyze the actions, objectives and operations of these actions and the ways that must be carried out to achieve these goals.

3 RESULT AND DISCUSSION

The problem of service level that was not achieved in this research was due to the large number of spare parts that were not available when it was needed for service. Due to large variation of items days of inventory (DOI) in average was more than target of 50 days.

First, the large variation of items should be classified into three categories using FSN to indicate fast-, slow-, and non-moving items, as shown in Table 1. Each item then categorized based on the number of movements in a year to show the days of inventories, as shown in Table 2.

3.1 Root Cause of the Problem (Analize)

Based on the problem definition, servile level performance still below target, that is 74%. Service level performance expected to be 80%. The other problem was days of inventory that was expected to be below 50 days but was still high in average 86 days. The root cause of these problem will be analyze using five whys method, as shown in Figure 4.

It was found that the root cause of the DOI and Service Level problems that were not achieved were the incorrect and efficient stock order process method, and the customer order process with an error in the parts number order and a new demand that counted in the service level.

3.2 Corrective Action

Based on the findings from five whys then the corrective action should be proposed using the problem identification and corrective action (PICA). The result was shown in Table 3.

Analyzing using PICA has found that process order stock can be improved using proper forecasting method and controlled using equivalent order quantity (EOQ) method. Then error in process order would be analyze further using human factors analysis and classification system (HFACS). The new demand can cause problem since it will lower service level, then vendor held stock (VHS) system will be proposed later.

Table 1: FSN Classification of Spare-parts Inventories

MM in Last 12 Month	Clasification
5-12 Month Movement	Fast Moving
1-4 Month Movement	Slow Moving
0 Month Movement	Non Moving

Table 2: Actual Stock Classification of Spare-parts Inventories in Year 2021

Target 50 Days						
FSN Analysis	Item	Qty	Price x Rp 1 million	ITO	DOI (Days)	% Stock Amount
Fast Moving	736	19102	5954	2	60	52%
Slow Moving	1196	5581	6206	5	148	45%
Non-Moving	7	8	399		∞	3%
Total	1939	24691	11559	3	86	100%

Table 3: Problem Identification and Corrective Action

Root Cause	Problem Identification	Corrective Action/Improvement Idea	Methods
Stock Order Process Methods	Inaccurate order processing item and qty (Excess and less)	Improvement forecasting and order qty	Forecasting/EOQ
Customer Order Proses Methods	Not careful in the order process for customers	Human error prevention and order process flow improvement	HFACS
	New demand lowers the service level because it is not included in the forecasting	Limitation of service level performance measurement coverage with VHS system	VHS & Task Analysis

Table 4: Forecasting Calculation

PN	Desc	DOI	Amt in Rp Million	2020												2021											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
561-01-72420	RUBBER	119	175	10	6	8	12	10	8	10	10	12	8	8	8	10	8	12	13	12	16	8	10	11	14	12	10
561-52-81211	PIN	115	156	6	5	9	9	9	9	8	6	10	10	5	7	8	7	9	7	10	8	9	7	9	10	6	8
235-70-11431	SPAC-ER	132	57						6		12		12										6	6	6	12	
566-02-6E151	ELBOW	640	83				2	2	4		2		3								3		2		4		5

3.3 Forecasting

The forecasting process using moving average model will be used to find the more appropriate forecasting method. The calculation using variation of 3 months, 6 months, and 12 months in 2021. Forecasting will be carried out using product sampling that represents the classification of Fast-moving and Slow-moving and then will use the Mean Absolute Deviation (MAD) method to measure the error rate of each forecasting calculation. Forecasting testing is carried out by sampling representative stock, namely 2 items of fast-moving and 2 items of slow-moving items, as shown in Table 4.

The formula used for the Moving average model is (Jay Heizer, Barry Render, Chuck Munson, 2010):

$$Ft = (\mathrm{Dt} - 1 + \mathrm{Dt} - 2 + \mathrm{Dt} - 3 + \cdots\cdots + \mathrm{Dt} - \mathrm{n})\,/\mathrm{n} \qquad (3)$$

Ft = Forecasting results in period t
Dt = Actual demand in period t

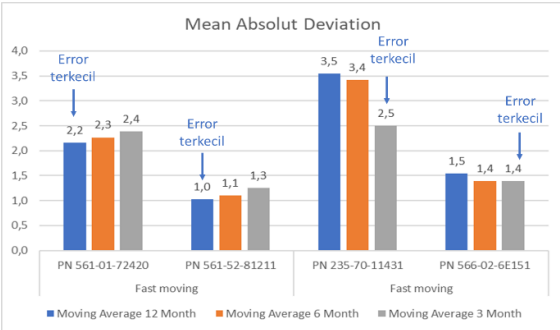

Figure 5: Mean Absolute Deviation

Calculation of the Mean Absolute Deviation (MAD) method with the following formula ((Jay Heizer, Barry Render, Chuck Munson, 2010):

$$MAD = \sum \left| \frac{Et}{N} \right| \tag{4}$$

MAD = (Absolute TotalValue (ActualDemand − ForecastingResult)) /12

From testing using a forecasting moving average model with 3 types of time series, namely 12 months, 6 months and 3 months and being tested using the MAD method, the results are as shown in Figure 5, so it is proposed to use the forecasting model as follows:

- For fast moving products, the best forecast is to use a 12-month moving average.
- For slow moving products, the best forecast is to use a 3-month moving average.

3.4 Inventory control

Inventory control needs to be done to minimize inventory costs, minimize stock outs which have an impact on service level declines and increase efficiency. In 2021 stock orders are carried out every month with a Qty Order of 1.5 x Forecast per month while in this study the method that will be used is the Economic Order Quantity (EOQ).

Formula EOQ (Jay Heizer, Barry Render, Chuck Munson, 2010):

$$\text{Economic Order Qty}(Q*) = \sqrt{\frac{2DS}{H}} \tag{5}$$

Apart from EOQ, Reorder Point (ROP) and safety stock are also determined.

$$\text{Reorder Point (d)} = \frac{\text{D}}{\text{Number of months in 1 year}} \tag{6}$$

D = Annual Demand
S = Purchase Cost
H = Handling Cost
Safety Stock = d x Safety factor for service level 80% is 0,84
Safety Factor = Standard factors based on service level according to Rahmat (2015), as shown in Table 5.

$$ROP\ (FinalReorderPoint) = (\text{d} \times \text{Lead Time (L)}) + \text{SafetyStock} \tag{7}$$

After the calculations were made by determining EOQ and ROP, it was found that with EOQ, the cost would be cheaper than the actual order process in 2021 which can be seen in Table 6, so the researcher proposed the EOQ method to be run in 2022 at PT. UT Bengalon

Table 5: Safety Factor Standard

Service Level	Safety Factor
50	0
75	0.67
80	0.94
85	1.04
90	1.28
94	1.56
95	1.65
96	1.75
97	1.88
98	2.05
99	2.33
99.86	3.00
99.99	4.00

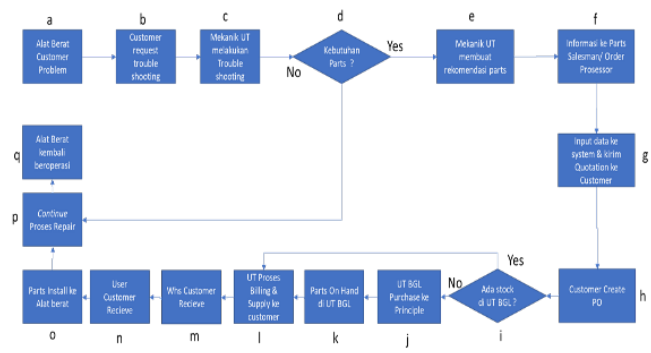

Figure 6: Flow Process Order Parts for Customer

3.5 Human Factors Analysis and Classification System

One of the causes of DOI not being achieved in heavy equipment parts stock at PT. UT Bengalon is a non-moving stock which is caused by a customer order cancellation due to an order error from PT. UT Bengalon. The flow process of ordering parts made by customer as shown in Figure 6. The cause of this process error occurs at:

- Step (e) is a part number recommendation error made by the mechanic
- Step (g) Part number input error, performed by Customer order processor and parts salesman.

Ishikawa diagram was used to identify the root cause of errors in process ordering parts. Analysis was conducted based on four categories, that is man, method, management, and tools, as shown in Figure 7. Based on Ishikawa diagram several problems was found following man, method, and management. Since these categories related to human factors, therefore human factors analysis and

Table 6: Comparation Actual Cost in 2021 with EOQ

Keterangan	PN 561-01-72420		PN 561-52-81211		PN 235-70-11431		PN 566-02-6E151	
	Actual 2021	EOQ	Actual 2021	EOQ	Actual 2021	EOQ	Actual 2021	EOQ
Q*	15	9	12	7	4	3	1	3
Biaya Pengadaan	1.200.000	1.500.000	1.200.000	1.400.000	1.200.000	800.000	1.200.000	400.000
Biaya Penyimpanan	8.140.321	3.875.105	8.691.747	4.379.562	15.097.199	6.491.000	2.904.404	2.005.422
Total Biaya	9.340.321	5.375.105	9.891.747	5.779.562	16.297.199	7.291.000	4.104.404	2.405.422
Efisiensi dengan EOQ	3.965.216		4.112.185		9.006.199		1.698.982	

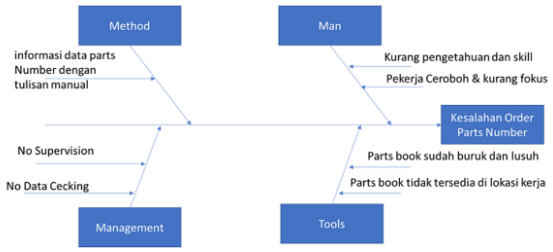

Figure 7: Ishikawa Diagram

classification system (HFACS) would be used for further analysis, as shown in Figure 8.

Recommendations given to employees, supervisors, and companies to prevent parts number order errors based on HFACS analysis are:

- Management provides coaching.
- Daily briefing in the morning meeting on a regular basis.
- Create a training system and refresh knowledge about reading parts book in a scheduled and consistent manner.
- Providing digital parts book facilities that are closer to mechanics.
- Supervisors must be disciplined in supervising the making of parts number recommendations.

Tindakan Tidak Aman		
Kesalahan	**Berbasis Ketrampilan**	**Tidak mampu mengidentifikasi parts number yang diperlukan sesuai dengan komponen yang diperlukan, spesifikasi model alat dan serial numbernya.**
	Keputusan	**Kurangnya rasa tanggung jawab.**
	Perseptual	**Tidak memahami dampak yang akan terjadi jika terjadi kesalahan dalam input parts number.**
Pelanggaran Rutin	**Tidak ada pengecekan parts number hasil rekomendasi dari mekanik.**	
	Tidak ada pengecekan parts number quotation yang dibuat oleh parts *salesman atau Customer order prosessor*.	
Prasyarat untuk tindakan tidak aman		
Faktor Lingkungan	**Fisik**	**Parts book yang kondisinya rusak, lusuh dan kurang terawat, menyebabkan kesalahan dalam pembacaan parts number**
	Tehnology	**Parts book digital atau soft file hanya digunakan pada computer di kantor dan tidak tersedia di lapangan atau lokasi kerja mekanik.**
		Transfer informasi parts number dengan tulisan manual
Kondisi Operator	**Keadaan Mental**	**Kurang Fokus dan kurang motivasi**
	Fisiologis	**Tidak ditemukan**
	Keterbatasan Fisik/Mental	**Tidak ditemukan**
Faktor Pribadi	**Crew Reaource management**	**Tidak ditemukan**
	Kesiapan Pribadi	**Kurang pengetahuan**
		Kurang bertanggung jawab
Pengawasan yang Tidak Aman		
Pengawasan yang Tidak Memadai	**Supervisor kurang memberikan coaching dan mekanik kurang mendapat pengetahunan tentang pembacaan parts book**	
Rencanakan Operasi yang Tidak Pantas	**Tidak ditemukan**	
Gagal Memperbaiki Masalah yang Diketahui	**Tidak ditemukan**	
Pengawasan Pelanggaran	**Tidak ada form standart pengecekan hasil rekomendasi oleh supervisor**	
Pengaruh Organisasi		
Manajemen Sumber Daya	**Kurang adanya event training dan refresh pembacaan parts book**	
Iklim Organisasi	**Kurang supervisi**	
	Tidak ada reward dan punishment	
Proses Operasional	**Tidak ada pemeriksaan ulang hasil rekomendasi dan quoatation**	

Figure 8: Human Factors Analysis and Classification System

Table 7: Slow Moving Items and Contribution to Availability of Parts

Month Movement	Item Not Available	Kontibusi Not Available	Keterangan
1	1237	64%	New Demand
2	592	31%	New Demand
3	50	3%	
4	45	2%	
Total Item Slow Moving	1924		

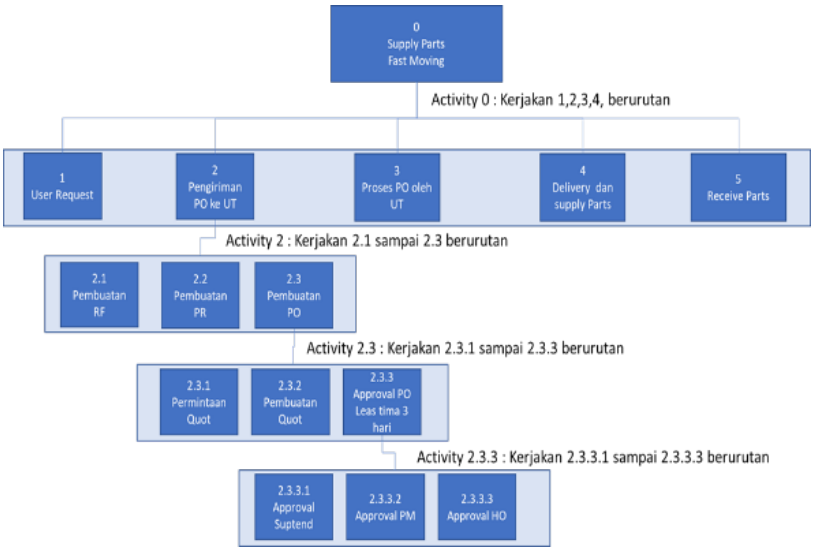

Figure 9: Task Analysis of Order Parts

- Make additional validation steps by the supervisor after the process of recommending parts number and making quotation.
- Create a work system with rewards and punishments to increase the responsibility and motivation of workers to work better and more thoroughly.

3.6 Vendor Held Stock (VHS) Improvement

First improvement will focus on service level problem for slow moving stock since the service level was only achieved at 57%. Table 7 shows that the biggest problems were the new parts demand. This request is categorized as new because the request has only occurred once or twice in the past 12 months, means that these items would not be able to forecast using historical data. For this reason, the Vendor Held Stock (VHS) system was necessary to be applied so that new demand items can be excluded from the service level calculations. The calculation of stock items in VHS system can be determined as follows:

- VHS Items only Items with a Month Movement of 3 Months and above.
- Fast Moving Items.
- Slow Moving items with 3- and 4-month month moves.
- Service level measurement is for VHS Items only.

Next the improvement would be done for reducing lead time for parts supply, since there was a lot of complaints regarding the supply of fast-moving parts still requires a long time because the process of purchasing orders normally take 3 days and 7 hours.

Hierarchy Task Analysis (HTA) was used to find the cause of longer lead time in ordering parts. The vendor held stock then was proposed, in which there is a supply agreement between vendor and customer, so that the lead time could be faster, as shown in Figure 9. In this situation, the purchase order was released collectively every 3 days after the spare parts supply. The lead time then can be reduced to only 5 hours, see Figure 10.

3.7 Forecasting and Inventory Control

Forecasting process is then will be calculated for fast moving and slow-moving items, following these procedures:

- For fast moving products, use a 12-month moving average
- For slow moving products, use a moving average of 3 months
- Testing accuracy with the MAD. Method

Forecasting method was conducted for January, February, March and April 2022 and the result can be seen in Figure 11.

The next step was calculating stock orders for four months in 2022 using Order Quantity (EOQ), the result is shown in Table 8.

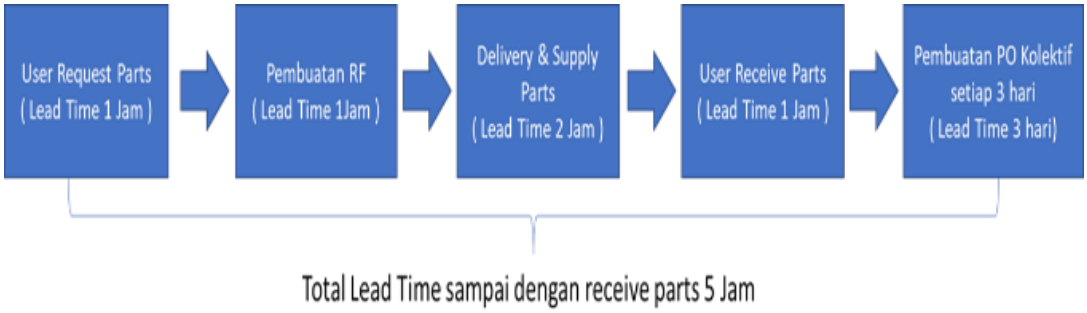

Figure 10: New Task Process Administration order parts

Table 8: Inventory cost.

Keterangan	PN 561-01-72420		PN 561-52-81211		PN 235-70-11431		PN 566-02-6E151	
	without EOQ	With EOQ	without EOQ	With EOQ	without EOQ	With EOQ	without EOQ	With EOQ
Q*	18	9	12	7	11	5	2	3
Purchase Cost (Rp)	400.000	0	400.000	200.000	400.000	300.000	400.000	200.000
Handling Cost (Rp)	17.896.354	9.791.792	17.610.893	7.087.311	6.422.136	2.071.657	2.276.845	1.555.931
Total Cost (Rp)	18.296.354	9.791.792	18.010.893	7.287.311	6.822.136	2.371.657	2.676.845	1.755.931
Efficiency with EOQ (Rp)	8.504.561		10.723.583		4.450.479		920.915	

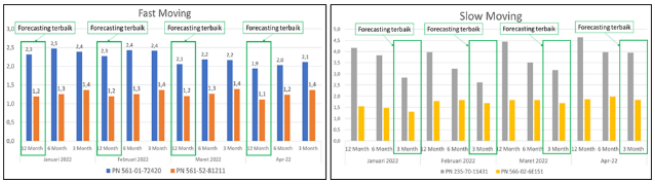

Figure 11: Measurement of Forecasting with MAD

After implementing the forecasting and inventory control methods, as shown in Figure 12 days of inventory, stock amount and service level have improved and reached its target.

4 CONCLUSION

The fluctuating demand of spare parts and inventory system at PT. UTB caused the service level below target and longer days of inventory. Based on Ishikawa diagram the root cause of this problem was the stock order process and the customer order process.

Forecasting procedure was then performed to make improvement in service level and decreasing days of inventory. Inventory Control is improved by using EOQ and Reorder Point methods.

Human factors analysis and classification system (HFACS) was used to find the root cause based on human. Prevention of Human Error was analyzed using the HFACS method and produced 7 recommendations covering aspects of employee skills and knowledge, employee attitudes and responsibilities, supervision and company management policies or influences.

Vendor held stock or VHS also introduced to prevent human error in parts ordering process, since VHS system is the most suitable inventory management system to improve service level measurement results and to accelerate spare parts supply lead time.

For future development of research results at PT. UTB to get a performance that can exceed the target and is sustainable, it is

Figure 12: Days of inventory, Stock Amount & Service Level after Improvements

recommended: Conducting in-depth research for the application of forecasting methods that have been recommended to become automatic forecasting systems so that they become the standard and avoid errors due to human error or inconsistency.

Conducting in-depth research related to improving employee competencies and behavior to increase a sense of responsibility to prevent human error on an ongoing basis.

Conducting in-depth research on the most appropriate method for managing new demand and unscheduled demand to increase the level of service standards for customers.

ACKNOWLEDGMENTS

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REFERENCES

[1] J. Heizer, B. Render, C. Munson, 2020, Operation Management
[2] R. Bridger. 2003. "*Introduction to Ergonomics* (2nd ed.)". Taylor dan Francis, Prentice Hall International
[3] Maserih, 2017. "Analisis Bullwhip dan DOI serta Implikasi terhadap supply chain (Studi kasus pada produk bpjs di PT XYZ Tbk".
[4] D.G. Brindha, (2014). "Inventory Management. *International Journal of Innovative Research in Science, Engineering and Technology"*, 3(1), 8163-8176.
[5] R. Naimullah. 2015. Modul Inventory Management "Kombinasi Teori dan Praktek Terbaik dalam Mengelola Inventory - Part 1". PQM Consultants.
[6] A. Trautrims , et. al. (2009). "Optimizing On-Shelf Availability for Customer Service And Profit". Journal of Business Logistics.
[6] R. Mustapha, Nurul Fadly Habidin, 2016. "Using DMAIC in Improvement of Customer Satisfaction and Facilities provided at Commuter Stations".
[7] Mind Tools Ltd. 2019. 5 "Whys Getting to the Root of a Problem Quickly"
[8] S. Wieczerniak, P. Cyplik, J Milczarek. "Root Cause Analysis Methods as A Tool Of Effective Change". Osijek, Croatia.
[9] A. Lusiana, P. Yuliarty. "Penerapan Methode Peramalan (Forecasting) Pada Permintaan Atap di PT.X"
[10] S. Chopra. 2007. Supply Chain Management; Strategy, Planning, and Operation. Third Edition. New Jersey: Pearson Education
[11] J. Annett, N.A. Stanton, (2000). "Task Analysis,London"Conference Name:ACM Woodstock conferenceConference Short Name:WOODSTOCK'18Conference Location:El Paso, Texas USA

Implementation of The Fuzzy Inference System to Determine The Amount of Purchase of Supplement Drug Products Based on Inventory and Sales Data at XYZ Pharmacy

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ABSTRACT

The Health Service Industry is one of the important and crucial industries to be maintained in order to support the welfare of the community. XYZ Pharmacy, which is located in the Jakarta area, is one of the industrial companies engaged in Health Services and focuses on the skin and genital area. The need for planning the number of purchases of medicinal products for Inventory at XYZ Pharmacy is very important. It was found that there were problems with the company, namely experiencing a very large amount of stock and decreasing stock in supplement products so that many products expired and lost customer trust. The purpose of this study was to determine the number of drug purchases at XYZ Pharmacy to reduce decreasing or excess drug stock. The method used in this study is the Fuzzy Sugeno and Fuzzy Mamdani method. The application of the Fuzzy Sugeno and Fuzzy Mamdani methods uses three variables, namely: the number of inventories, the number of sales, and the number of drug purchases with the help of MATLAB software. Determination of safety stock and reorder points conducted by XYZ Pharmacy is carried out to minimize inventory running out which has an impact on customer satisfaction levels. The results of this study are In Fuzzy Mamdani's calculation, the Enervon C Tab Strip 4S/25 STRP product has a fulfilled presentation result of 79%. In Fuzzy Sugeno's calculation, the Enervon C Tab Strip 4S/25 STRP product has a fulfilled presentation result of 31%. It can be concluded that the application of Fuzzy Mamdani is better than the Fuzzy Sugeno method for calculating the inventory of Enervon C Tab Strip 4S/25 STRP products. In the calculation of the Safety Stock of the Enervon C Tab Strip 4S/25 STRP product, the results are 75 packs per month with reorder points of 80 packs per month for Calcium Carbonat + Vitamin D3 400 of 61 packs per month with reorder points of 65 packs per month.

CCS CONCEPTS

• **Insert your first CCS term here**; • **Insert your second CCS term here**; • **Insert your third CCS term here**;

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KEYWORDS

Fuzzy inference system, Inventory, Purchases and Sales, Safety stock

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1 INTRODUCTION

The health care industry is one of the most important sectors that has a great influence on people's welfare. One of the health service industries is pharmaceutical services or known as pharmacies. Pharmacy is one of the health services that help, maintain, and realize the community in the creation of optimal health. One of the most important elements in the operation of a pharmacy is the inventory element. The right supply of drugs in the pharmacy will affect the performance and activities in terms of operations. In inventory storage, there needs to be a more effective and efficient way to organize and control large amounts of inventory. Without proper supplies, pharmacies will be faced with the risk of not being able to meet the needs of their customers. Inventory is carried out to ensure certainty that when needed these products are available [1].

This study uses the application of the Fuzzy Inference System method, which can be used to optimize the amount of drug inventory for each certain time period and determine the right time to purchase drugs for supplies at the pharmacy. In the Fuzzy Inference System method, this study made observations using the Fuzzy Sugeno method to determine the number of purchases of supplemental medicinal products. The calculation of the Sugeno method has an output of constant numbers or linear equations. This method has the advantage of being very clear and easy to use compared to other methods.

Determination of sufficient stock, excess, and shortage of stock is calculated based on the reduction of the amount of inventory with the number of sales. The Enervon C Tab Strip 4S/25 STRP Supplement ran out of stock in October 2020 and July 2021 and experienced very thin stock and sometimes even sales that exceeded the existing inventory. Because of this problem, customers will usually move to another place with very complete product conditions. In table 1, the months of January, March, May, June, and August

Table 1: Enervon C Tab Strip 4S/25 STRP supplement data sample

Year 2020/2021	Supplement Drugs			Description
	Enervon C Tab Strip 4S/25 STRP			
	Inventory	Sales	Purchase	
September	25	25	0	Sufficient stock
October	0	0	0	Sufficient stock
December	150	100	150	Excess stock 50 pack
January	50	70	0	Short stock 20 pack
February	130	100	150	Excess stock 30 pack
March	130	150	100	Short stock 20 pack
April	105	73	125	Excess stock 32 pack
May	32	75	0	Short stock 43 pack
June	-43	3	0	Short stock 40 pack
July	29	100	75	Short stock 71 pack
August	-21	25	50	Short stock 46 pack

have a number of stocks that are less than the total sales, so the company borrows drugs from other pharmacies to meet the number of customer requests. There is a sample data for the Enervon C Tab Strip 4S/25 STRP supplement for the period September 2020 to August 2021 in Table 1.

The objectives to be achieved in this research are as follows:

- Determining the number of purchases of supplementary medicinal products Enervon C Tab Strip 4S/25 STRP using the Fuzzy Mamdani method and the Fuzzy Sugeno method based on three input variables of inventory, purchases, and sales at XYZ Pharmacy.
- Knowing the minimum amount of drug stock (safety stock) that is carried out to meet customer demand at the XYZ Pharmacy on Enervon C Tab Strip 4S/25 STRP supplement drug products
- Knowing the reorder point or reorder point that is used by XYZ Pharmacy in fulfilling customer requests at XYZ Pharmacy on Enervon C Tab Strip 4S/25 STRP supplement drug products

2 FUZZY

2.1 Fuzzy Logic

Tables are "float elements" which should be inserted after their first text reference and have specific styles for identification. Do not use images to present tables, or they will be inaccessible to readers using assistive technologies. Fuzzy logic was first developed by Lotfi A Zadeh in 1965 who is a professor at the University of California, Berkeley [3]. There are several things that need to be known in understanding the fuzzy system, namely:

1. Fuzzy variable is a variable to be discussed in a fuzzy system. Examples are: age, temperature, speed, and distance [2].
2. Fuzzy set is a group that represents a certain condition or condition in a fuzzy variable. Fuzzy set has 2 attributes [2], namely:

1. Linguistics, namely naming a group that represents a certain situation or condition using natural language, such as: Near, Medium, Far
2. Numeric, which is a value (number) that indicates the size of a variable, such as: 30,40,45.
3. The universe of speech is the entire value obtained for operation in a fuzzy variable, the universe of speech is a set of real numbers that always increases (increases) monotonically from left to right [2]. For example, the universe of talks for the temperature variable: [0 40].
4. Domain is the entire value that is allowed in the universe of talk and can be operated in a fuzzy set [2]. Like the universe of conversation, the domain is a set of real numbers that always increases (increases) monotonically from left to right as shown in Figure 6.2. Examples of domains are Near [0 5], Medium [7, 10], and Far [15, 20].

2.2 Fuzzy Mamdani

This method was first proposed by Ebrahim Mamdani in 1975. This method is the simplest method and is often used for research compared to other methods [6]. To determine the output there are several stages, namely:

a. The formation of a fuzzy set is that there are input and output variables.
b. Fuzzyfication is done to squeeze a crisp number into the fuzzy variable from the input variable.
c. Implication, is used to determine the form of the final fuzzy number which is determined by filling the fuzzy output set into the output variable.
d. Aggregation is the process of combining the output functions of the implication process by following the IF THEN rules into a single fuzzy set using the MAX function.
e. Deffuzyfication, this process uses the input of a fuzzy set obtained from the applicable fuzzy rules and the output is the domain number of the fuzzy set. In general, it can be written using equation 2) as follows:

$$X = \frac{\int_1^x x\mu(x)\,dx}{\int_1^x \mu(x)\,dx} \tag{1}$$

Information:
x = output variable

X = Fuzzy output area center point
μ(x) = membership function of the output variable

2.3 Fuzzy Sugeno

In the Sugeno method, fuzzification, fuzzy operations, and implications are the same as the Mamdani method. The difference is only in aggregation and defuzzification. If in the Mamdan method the aggregation is the area under the curve, then in the Sugeno method the aggregation is in the form of singletons.

Defuzzification in the Sugeno method is simpler, because it only calculates the center of single-ton

$$z^* = \frac{\sum \mu_c(\bar{z}) \cdot \bar{z}}{\sum \mu_c(\bar{z})} \tag{2}$$

which in this case, $\bar{z}$ is the singleton value

3 RESEARCH METHODOLOGY

Research Methodology is the stages or steps of the process flow in conducting systematic and precise research so as to get good research results. The research method used is the Fuzzy Inference System, namely Fuzzy Sugeno. The initial stage begins with identifying the problems that occur. To clarify the research methodology, a flow chart is made as shown in Figure 1.

4 RESULT

4.1 Safety Stock

Calculation of safety stock using data that is a service level of 95% with a service factor of 1.64 and data on the average number of sales per month. With the safety stock formula, the following results are obtained:

- Enervon C Tab Strip 4S/25 STRP:

Sample	x	x^2
September	25	625
October	0	0
November	50	2500
December	100	10000
January	70	4900
February	100	10000
March	150	22500
April	73	5329
May	75	5625
June	3	9
July	100	10000
August	25	625
Total	**771**	**72113**

Calculation:

$$SS = Z\ x\ \sigma$$

$$SS = 1,64\ x \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}}$$

$$SS = 1,64\ x \sqrt{\frac{72113 - \frac{(771)^2}{12}}{12-1}}$$

$$SS = 1,64\ x\ 45,303$$

$$SS = 74,297 = 75\ pack$$

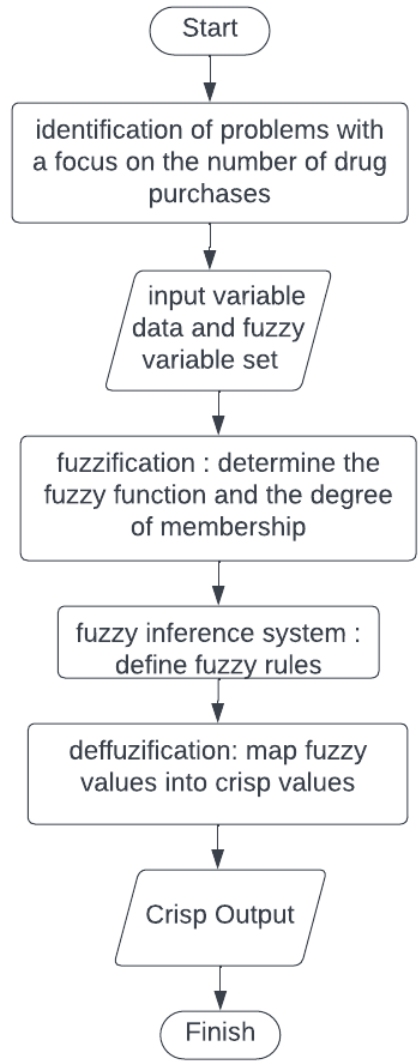

Figure 1: Fuzzy Methodology Flowchart

The safety stock for the Enervon C Tab Strip 4S/25 STRP product is 75 packs.

4.2 Reorder Point

The reorder point is the time when a reorder must be held so that the inventory can be above the safety stock or equal to zero. After the safety stock has been obtained, you can calculate the reorder point value. With the reorder point formula, the following results are obtained:

$$ROP = (d\ x\ L) + SS$$

$$ROP = \left(\frac{771}{365}\ x\ 2\right) + 75$$

$$ROP = 79,22\ \approx 80\ pack$$

4.3 Solving with Fuzzy Mamdani Method

a. Fuzzification

There are 3 fuzzy variables modeled in this study, namely:

- Inventory (psd): consists of 3 fuzzy sets, namely: low, medium, and high.
- Sales (pjl): consists of 3 fuzzy sets, namely: decreasing, normal, and increasing.
- Purchases (pbl): consists of 3 fuzzy sets, namely: few, medium, and many.

b. Fuzzy Rules

After performing the Fuzzyfication stage, then the formation of fuzzy logic rules is carried out. In this study, nine possible combinations were obtained from the number of variables from each fuzzy set that was formed. The rules are as follows:

- IF (Inventory is Low) and (Sales is Decreasing) then (Purchases is Few)
- IF (Inventory is Normal) and (Sales is Decreasing) then (Purchases is Few)
- IF (Inventory is High) and (Sales is Decreasing) then (Purchases is Few)
- IF (Inventory is Low) and (Sales is Normal) then (Purchases is High)
- IF (Inventory is Normal) and (Sales is Normal) then (Purchases is Normal)
- IF (Inventory is High) and (Sales is Normal) then (Purchases is Few)
- IF (Inventory is Low) and (Sales is Increasing) then (Purchases is Many)
- IF (Inventory is Normal) and (Sales is Increasing) then (Purchases is Many)
- IF (Inventory is High) and (Sales is Increasing) then (Purchases is Many)

c. Determining the compositions of the rule

In this study, taking one of the product samples, namely Enervon C Tab Strip 4S/25 STRP in the September 2021 period with a total inventory of 25 packs, a total purchase of 0 packs, and a total sales of 25 packs, so that a value is obtained for each variables are as follows:

- Inventory Variable

$\mu psdLOW\ (25) = \frac{90-25}{90-(-50)} = \frac{65}{140} = 0,464$

$\mu psdNORMAL\ (25) = 0$

$\mu psdHIGH\ (25) = 0$

- Sales Variables

$\mu pjlDECREASING\ (25) = \frac{80-25}{90-0} = \frac{55}{90} = 0,611$

$\mu pjlNORMAL\ (25) = 0$

$\mu pjlINCREASING\ (25) = 0$

- Purchase Variables

$\mu pblFEW\ (0) = 1$

$\mu pblNORMAL\ (0) = 0$

$\mu pblMANY\ (0) = 0$

After performing the Fuzzyfication stage which determines the degree of membership for each fuzzy set and forms the fuzzy rules of each related fuzzy variable, the next step that needs to be done is to compose the fuzzy basic rules. The following is the composition of the rules formed, namely:

1. IF (Inventory is Low) and (Sales is Decreasing) then (Purchases is Few)

$$\alpha - predikat1 =$$
$$= \mu_{PsdLOW} \cup \mu_{PjlDECREASING}$$
$$= \mu_{PsdLOW}\ (25) \cup \mu_{pJLDECREASING}\ (25)$$
$$= \min\ (0,464; 0,611) = 0,464$$

When $\mu_{PblFEW} = 0.464$ then the value of x can be determined as follows:

$$\alpha - predikat1 =$$
$$= \frac{90-x}{90} \qquad = 0,464$$
$$(90x0,464) \qquad = 90 - x$$
$$x \qquad = 48,24$$

2. IF (Inventory is Normal) and (Sales is Decreasing) then (Purchases is Few)

$$\alpha - predikat2 =$$
$$= \mu_{PsdNORMAL} \cup \mu_{PjlDECREASING}$$
$$= \mu_{PsdNORMAL}\ (25) \cup \mu_{PjlDECREASING}\ (25)$$
$$= \min\ (0; 0,611)$$
$$= 0$$

No fuzzy output region is formed

3. IF (Inventory is High) and (Sales is Decreasing) then (Purchases is Few)

$$\alpha - predikat3 =$$
$$= \mu_{PsdHIGH} \cup \mu_{PjlDECREASING}$$
$$= \mu_{PsdHIGH}\ (25) \cup \mu_{PjlDECREASING}\ (25)$$
$$= \min\ (0; 0,611)$$
$$= 0$$

No fuzzy output region is formed

4. IF (Inventory is Low) and (Sales is Normal) then (Purchases is High)

$$\alpha - predikat4 =$$
$$= \mu_{PsdLOW} \cup \mu_{PjlNORMAL}$$
$$= \mu_{PsdLOW}\ (25) \cup \mu_{pJLNORMAL}\ (25)$$
$$= \min\ (0,464; 0)$$
$$= 0$$

No fuzzy output region is formed

5. IF (Inventory is Normal) and (Sales is Normal) then (Purchases is Normal)

$$\alpha - predikat5 =$$
$$= \mu_{PsdNORMAL} \cup \mu_{PjlNORMAL}$$
$$= \mu_{PsdNORMAL}\ (25) \cup \mu_{pJLNORMAL}\ (25)$$
$$= \min\ (0; 0)$$
$$= 0$$

No fuzzy output region is formed

6. IF (Inventory is High) and (Sales is Normal) then (Purchases is Few)

$$\alpha - predikat6 =$$
$$= \mu_{PsdHIGH} \cup \mu_{PjlNORMAL}$$
$$= \mu_{PsdHIGH}\ (25) \cup \mu_{pJLNORMAL}\ (25)$$
$$= \min\ (0; 0)$$

$= 0$

No fuzzy output region is formed

7. IF (Inventory is Low) and (Sales is Increasing) then (Purchases is Many)

$\alpha - predikat7 =$
$= \mu_{PsdLOW} \cup \mu_{PjlINCREASING}$
$= \mu_{PsdLOW}(25) \cup \mu_{PjlINCREASING}(25)$
$= \min(0,464; 0)$
$= 0$

No fuzzy output region is formed

8. IF (Inventory is Normal) and (Sales is Increasing) then (Purchases is Many)

$$\alpha - predikat8 =$$
$$= \mu_{PsdNORMAL} \cup \mu_{PjlINCERASING}$$
$$= \mu_{PsdNORMAL}\ (25) \cup \mu_{PjlINCERASING}\ (25)$$
$$= \min\ (0; 0)$$
$$= 0$$

No fuzzy output region is formed

9. IF (Inventory is High) and (Sales is Increasing) then (Purchases is Many)

$$\alpha - predikat9 =$$
$$= \mu_{PsdHIGH} \cup \mu_{PjlINCERASING}$$
$$= \mu_{PsdHIGH}\ (25) \cup \mu_{PjlINCERASING}\ (25)$$
$$= \min\ (0; 0)$$
$$= 0$$

No fuzzy output region is formedd. Deffuzification

The last stage in the research with Fuzzy Mamdani is the stage of affirmation (deffuzyfication). The steps in deffuzification with the Centroid method are as follows:

The first inference is a linear function, so:

$$M1 = \int_{0}^{48,24} 0,464\ x\ dx$$

$$M1 = \left.\frac{0,464\ x^2}{2}\right|_{0}^{48,24}$$

$$M1 = (0,232)\ (48,24)^2 - (0,232)\ (0)^2$$

$$M1 = 539,887$$

Area for the first Inference:
$A1 = (0,464)\ (48,24 - 0)$
$A1 = 22,384$

The second inference is an ascending function, so:

$$M2 = \int_{48,24}^{90} \frac{90 - x}{90 - 0} x\ dx$$

$$M2 = \left.\frac{90\ x^2}{2\ (90)} - \frac{x^3}{3\ (90)}\right|_{48,24}^{90}$$

$$M2 = \left(\frac{90\ (90)^2}{2\ (90)} - \frac{(90)^3}{3\ (90)}\right) - \left(\frac{90\ (48,24)^2}{2\ (90)} - \frac{(48,24)^3}{3\ (90)}\right)$$

$$M2 = 602,225$$

Area for the second Inference:

$$A2 = (0,464)\ \left(\frac{(90 - 48,24)}{2}\right)$$

$$A2 = 9,69$$

The center point can be obtained as follows:

$$z* = \frac{\int_a^b x.\mu\ (x)\ .dx}{\int_a^b \mu\ (x)\ .dx}$$

$$z* = \frac{M1 + M2}{A1 + A2}$$

$$z* = \frac{539,887 + 602,225}{22,384 + 9,69}$$

$$z* = 35,608\ \approx 36$$

In the Enervon C Tab Strip 4S/25 STRP product, the excess remaining inventory can be said to be good because the sales of these products are quite fast and are in demand by customers. The calculation results were carried out on the percentage of Enervon C Tab Strip 4S/25 STRP product fulfillment, which was 79%. The following table shows the results of the number of purchases using the Fuzzy Mamdani method for Enervon C Tab Strip 4S/25 STRP product in Table 3.

4.4 Solving with Fuzzy Sugeno Method

a. Fuzzy Rules

- IF (Inventory is Low) and (Sales is Decreased) then (Buying is mf1)
- IF (Inventory is Medium) and (Sales is Decreased) then (Buying is mf1)
- IF (Inventory is High) and (Sales is Decreased) then (Buying is mf1)
- IF (Inventory is Low) and (Sales is Normal) then (Purchases is mf2)
- IF (Inventory is Medium) and (Sales is Normal) then (Purchase is mf2)
- IF (Inventory is High) and (Sales is Normal) then (Purchases is mf2)
- IF (Inventory is Low) and (Sales is Increase) then (Buying is mf3)
- IF (Inventory is Medium) and (Sales is Increase) then (Purchasing is mf3)
- IF (Inventory is High) and (Sales is Increase) then (Buying is mf3)

Where
mf1 = $\sum(average\ number\ of\ demand) = 65$
mf2 = $\sum(average\ number\ of\ demand) + 10 = 75$ mf3 = $\sum(average\ number\ of\ demand) + 20 = 85$ **b. Determining the compositions of the rule**

Similar to the use of the Mamdani method, the Sugeno method, After performing the Fuzzyfication stage which determines the degree of membership for each Fuzzy set and forms the Fuzzy rules from each of the related Fuzzy variables, the next step that needs to be done is to compose the Fuzzy basic rules. The fuzzy operators that will be used are AND and -predicate

c. Defuzzification

Fuzzy Sugeno method uses a weighted average derived from the calculation of the composition of the rules on the nine formed rules. The equation obtained is as follows

$$z = \frac{\sum_{a=1}^{9} x_a \mu\ (x_a)}{\sum_{a=1}^{9} \mu\ (x_a)}$$

Table 3: Result of Purchase of Fuzzy Mamdani Enervon C Tab Strip 4S/25 STRP method

Year 2020/2021	Supplement Medicine			Stock	Safety Stock	Fulfilled/not	Percentage
	Enervon C Tab Strip 4S/25 STRP						
	Inventory	Sales	Purchase				
September	25	25	0	36	75	not fulfilled	-52%
October	0	0	0	71	75	not fulfilled	-5%
November	50	50	50	92	75	fulfilled	23%
December	150	100	150	83	75	fulfilled	11%
January	50	70	0	122	75	fulfilled	63%
February	130	100	150	113	75	fulfilled	51%
March	60	150	100	107	75	fulfilled	43%
April	10	73	125	118	75	fulfilled	57%
May	78	75	0	171	75	fulfilled	128%
June	3	3	0	203	75	fulfilled	171%
July	75	100	75	244	75	fulfilled	225%
August	25	25	50	254	75	fulfilled	239%
			Mean				79%

Table 4: Result of Purchase of Fuzzy Sugeno Enervon C Tab Strip 4S/25 STRP method

Year 2020/2021	Supplement Medicine			Stock	Safety Stock	Fulfilled/Not	Percentage
	Enervon C Tab Strip 4S/25 STRP						
	Inventory	Sales	Purchase				
September	90	65	25	65	75	Not fulfilled	-13%
October	130	65	0	130	75	Fulfilled	73%
November	198	68	50	148	75	Fulfilled	97%
December	228	80	100	128	75	Fulfilled	71%
January	201	73	70	131	75	Fulfilled	75%
February	211	80	100	111	75	Fulfilled	48%
March	196	85	150	46	75	Not fulfilled	-39%
April	120	74	73	47	75	Not fulfilled	-37%
May	121	74	75	46	75	Not fulfilled	-39%
June	111	65	3	108	75	Fulfilled	44%
July	188	80	100	88	75	Fulfilled	17%
August	153	65	25	128	75	Fulfilled	71%
			Mean				31%

Before calculating with Fuzzy Sugeno, there was a stock shortage that occurred in Enervon C Tab Strip 4S/25 STRP products in January, February, May, June, July, and August 2021. After calculating with Fuzzy Sugeno, the stock was fulfilled and can meet customer needs at XYZ Pharmacy. In the Enervon C Tab Strip 4S/25 STRP product, the excess remaining inventory can be said to be good because the sale of the product is quite fast and is in demand by customers. When viewed from the number of safety stock that has been carried out in the previous calculation, in September 2020, March, April, and May 2021, the remaining inventory results were not met according to the safety stock with a total of 75 packs. The calculation results were carried out on the percentage of Enervon C Tab Strip 4S/25 STRP product fulfillment, which was 31%.

5 CONCLUSION

Based on the results of the application of Fuzzy Sugeno to determine the number of purchases for Enervon C Tab Strip 4S/25 STRP products, it can be concluded as follows:

1. In Fuzzy Mamdani's calculation, the Enervon C Tab Strip 4S/25 STRP product has a fulfilled presentation result of 79% while the Enervon C Tab Strip 4S/25 STRP product has a fulfilled presentation result of 79%. It can be concluded that the application of Fuzzy Mamdani is better than the Fuzzy Sugeno method for calculating the inventory of Enervon C Tab Strip 4S/25 STRP products.
2. In the calculation of safety stock, for Enervon C Tab Strip 4S/25 STRP, the results are 75 packs per month, while

(1) In the calculation of the reorder point, the results are 80 packs per month

REFERENCES

[1] Sitio dan S.L.Mulani, Penerapan Fuzzy Inference System Sugeno untuk *Menentukan Jumlah Purchases Obat (Studi Kasus: Garuda Sentra Medika).* Jurnal Informatika Universitas Pamulang, 3(2), 104, 2018.

[2] S. Kusumadewi dan H. Purnomo. *Aplikasi Logika Fuzzy untuk Pendukung Keputusan.* Yogyakarta; Graha Ilmu, 2004.

[3] S. Batubara, "Analisis Perbandingan Metode *Fuzzy* Mamdani Dan *Fuzzy* Sugeno Untuk Penentuan Kualitas Cor Beton Instan," *It J. Res. Dev.,* vol. 2, no. 1, pp. 1–11, 2017, doi: 10.25299/itjrd. 2017. vol2 (1). 644.

[4] B. Warsito, A. Rusgiyono, and M. A. Amirillah, "Pemodelan General Regression Neural Network Untuk Prediksi Tingkat Pencemaran Udara Kota Semarang," Media Stat., vol. 1, no. 1, 2012, doi: 10.14710/medstat.1.1.43-51.

[5] Yulamini, "Penggunaan Metode *Fuzzy* Inference System (Fis) Mamdani Dalam Pemilihan Peminatan Mahasiswa Untuk Tugas Akhir," J. Inform. Darmajaya, vol. 15, no. 1, pp. 10–23, 2015, doi: 10.30873/ji. v20i2.

[6] Setiadji. Himpunan dan Logika Samar serta Aplikasinya. Yogyakarta: Graha Ilmu, 2009.

[7] S. Kusumadewi. Analisis & Desain Sistem Fuzzy Menggunakan Toolbox Matlab. Yogyakarta; Graha Ilmu, 2002.

[8] A. Naba dan F.I.S.Suryantoro. *Belajar cepat Fuzzy Logic menggunakan mattlab.* Yogyakarta: Andi Offset, 2009

[9] S. Assauri. *Manajemen Produksi & Operasi.* Jakarta: LBFE UI, 1980

[10] D. Sunyoto. *Manajemen dan Pengembangan Sumber Daya Manusia.* Yogyakarta: Center for Academic Publishing Service, 2015

[11] H.M. Jogiyanti. *Analisis dan Desain Sistem Informasi.* Yogyakarta: Andi Offset, 1990

[12] Modul Apsi 2021, Universitas Trisakti, Jakarta, Indonesia, 2021, 1.1-IV.14

[13] James W. Demmel, Yozo Hida, William Kahan, Xiaoye S. Li, Soni Mukherjee, and Jason Riedy. 2005. Error Bounds from Extra Precise Iterative Refinement. Technical Report No. UCB/CSD-04-1344. University of California, Berkeley.

[14] David Harel. 1979. First-Order Dynamic Logic. Lecture Notes in Computer Science, Vol. 68. Springer-Verlag, New York, NY. https://doi.org/10.1007/3-540-09237-4

[15] Jason Jerald. 2015. The VR Book: Human-Centered Design for Virtual Reality. Association for Computing Machinery and Morgan & Claypool.

[16] Prokop, Emily. 2018. The Story Behind. Mango Publishing Group. Florida, USA.

[17] R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

[18] Brian K. Reid. 1980. A high-level approach to computer document formatting. In Proceedings of the 7th Annual Symposium on Principles of Programming Languages. ACM, New York, 24–31. https://doi.org/10.1145/567446.567449

[19] John R. Smith and Shih-Fu Chang. 1997. Visual Seek: a fully automated content-based image query system. In Proceedings of the fourth ACM international conference on Multimedia (MULTIMEDIA '96). Association for Computing Machinery, New York, NY, USA, 87–98. https://doi.org/10.1145/244130.244151

[20] TUG 2017. Institutional members of the LaTeX Users Group. Retrieved May 27, 2017 from http://wwtug.org/instmem.html

[21] Alper Yilmaz, Omar Javed, and Mubarak Shah. 2006. Object tracking: A survey. ACM Comput. Surv. 38, 4 (December 2006), 13–es. https://doi.org/10.1145/1177352.1177355

Sustainable Export Strategy of Used Cooking Oil SME in Indonesia

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ABSTRACT

This research aims to help company as SME in used cooking oil industry to discover and understand the internal and external conditions, explore their strengths and opportunities, and provide recommendations for the right export strategy to face competition with similar competitors to increase sales. This descriptive research uses primary and secondary data. Primary data is collected by interviewing key persons of the company and secondary data is collected from journals, articles and other relevant professional sources. The data analysis technique used in this research is 7S McKinsey analysis, PESTEL analysis, SWOT analysis, and TOWS Matrix. This study found that the strategy recommendation for SME in used cooking oil is market penetration through digital marketing.

CCS CONCEPTS

• **Environtment**; • **Business Process Management**;

KEYWORDS

Sustainable, Export, Strategy, SME, Used cooking oil

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1 INTRODUCTION

The need for main energy sources such as petroleum, coal and gas, certainly will experience an increase in utilization, along with the national development currently being carried out by the Indonesian government in various fields/sectors [1]. As a country that is blessed with overflowing natural resources, it is a reasonable thing for Indonesia to use its natural resources as energy resources to support the government's development plans. There are two types of energy sources used today, namely non-renewable energy sources and renewable energy sources. Non-renewable energy sources are energy sources that can run out and cannot be recycled. This energy source takes a very long time to be re-created, because non-renewable energy sources come from plant and animal fossils that have been buried for millions of years in the earth and turned into petroleum. While renewable energy sources are energy sources which can be recycled and can be renewed and are available in large quantities. Currently what has been used is energy from biogas, water, wind, and sunlight [2]. It is undeniable that the use of non-renewable energy resources that are too massive will certainly have a negative impact on the environment and nature.

Indonesia is rich in renewable energy sources, which are often referred to as alternative resources. Development of alternative energy sources is useful so that Indonesia does not continue to depend on non-renewable energy resources, which are depleting and may run out one day [3]. This reason also underlies, every country has begun to develop new technologies to find alternative energy sources as a substitute for non-renewable energy. Bioethanol, biodiesel, and biogas are types of biofuels [4]. Biofuels are energy made from living matter, usually plants. Biofuels are considered renewable energy, decreasing the role of fossil fuels and have received attention in the transition to a low-carbon economy. Biodiesel is an example of a renewable energy source. Biodiesel is an alternative fuel produced from renewable natural materials such as vegetable oil and animal oil [5]. One of the raw materials for biodiesel is used cooking oil [6]. Used cooking oil itself is used oil, it can be used for household needs, restaurant needs and others. This oil includes palm oil and all other cooking oils. The high potential of used cooking oil in

Indonesia makes used cooking oil to be considered as a promising business, for the biodiesel domestic use as well as export.

The export value of used cooking oil continues to increase. In the publication of Indonesia Oilseeds and Products Annual 2021 it is known that household cooking oil consumption in Indonesia reaches 13 million [7], it's very potential market. Data from the United States Department of Agriculture or USDA shows the countries that consumed the most cooking oil in 2019 in a row, namely Indonesia, India, China, and Malaysia. This high level of consumption of cooking oil then produces residue in the form of used cooking oil in Indonesia. TNP2K's and Asia Traction Energy initial review on the Potential of Waste Cooking Oil for Biodiesel and Poverty Reduction in Indonesia [8]. The national consumption of palm cooking oil in 2021 reached 16.2 million kiloliters (KL) [7].

The promising potential of used cooking oil is utilized by various organizations and companies to gain profit. Many companies are currently exporting used cooking oil, since there is still a huge international market. Customs region is defined as a region with specified borders in seaports, airports, or other sites that are specially meant for goods traffic under the supervision of the Directorate General of Customs and Excise. Export activities usually happen when a country is capable to mass produce goods or services, such that it has satisfied the local demand. Indonesia's main export commodities are still dominated from the plantation and agriculture sector, or in other words, Indonesia's natural resources.

Company collects used cooking oil from various suppliers then processes and tests it. Waste cooking oil that passes the lab test is then exported to various countries such as South Korea, the Netherlands, and India, as raw material for biodiesel. In developing its business, the company is faced with various challenges such as competition between competitors, and the decreasing volume of used cooking oil from suppliers. The high potential of used cooking oil is utilized by many organizations or companies for profit. Many companies export used cooking oil, because the international market potential is still wide open. Early studies of TNP2K and Asia's Energy Traction regarding the potential of used cooking oil for biodiesel and poverty reduction in Indonesia recorded that in 2019, consumption of palm cooking oil reached 16.2 million kiloliters (KL). From that figure, the average quantity of used cooking oil produced is between 40-60% (6.46-9.72 KL).

Unfortunately, the used cooking oil that can be collected in Indonesia has only reached 3 million KL or only 18.5% of the total national consumption of palm cooking oil [9]. The study found that only a small proportion of used cooking oil in Indonesia is used as biodiesel. Of the 3 million KL that was collected, only about 570 KL was converted for biodiesel and other needs, while the remaining 2.4 million kiloliters was used for recycled cooking oil and exports. There are also many Indonesian people who do not know that used cooking oil can be used and also has a selling value, this causes the absorption of used cooking oil to be less than optimal. For this reason, this study is needed to find out which export strategies should be carried out by companies in exporting used cooking oil as biodiesel raw material.

Based on this background, this research is required to explore the factors that affect business strategies in exporting used cooking oil as the raw material of biodiesel and to recommend the most appropriate business strategy to be implemented by companies.

2 LITERATURE REVIEW

In analyzing the internal environment, McKinsey 7S analysis is used. Mckinsey's 7S is a management model that outlines 7 factors to manage a company effectively and holistically. All these factors together determine the company's operations [10]. These company leaders must consider the seven factors in this model, to ensure the successful implementation of the relevant organizational strategies. The role of each factor does not matter, whether small or large, because all these factors depend on each other. The importance of each factor will change during the development of the organization [11]. Seven variables that influence the success of an organization are summarized in McKinsey's 7S, namely Strategy and Structure, Style, System, Staff, Skill, and Shared values.

In analyzing the external environment, PESTEL analysis is used. According to Kremmer & Symmons [12], PESTEL is a multifaceted approach to assessing the power of the big picture to better understand an organization's strategic orientation as well as assist in making considered and informed decisions about an organization's activities. The PESTEL framework mainly concerns six factors: Political, Economic, Social, Technological, Environmental, and Legal. As a structured way to regulate environmental factors, PESTEL is used to analyse and map how the external environment affects an industry [13]. This tool provides an overview of the macro-environmental factors that companies need to consider in their decision making [14]. Taking into account the main external drivers of change, the PESTEL framework can encourage companies to consider long-term goals and to choose sustainable business innovation and investment strategies. [15]

SWOT analysis is a method that is widely used in strategy development, strategic planning, and decision making [16]. Strengths and weaknesses are known as internal factors and opportunities and threats are external factors. In other words, the strength and weakness factors are identified through the internal system environmental assessment, while the opportunity and threat factors are identified through the external system environmental evaluation [17].

SWOT analysis provides a list of strengths, weaknesses, opportunities, and threats related to the internal and external environment that affect a system within the organization. The TOWS concept is closely related to SWOT analysis. The sequence of problem solving in the strategy formulation process should be analyzed in the following order Threats, Opportunities (in the environment) Weaknesses, Strengths (of the organization) [17]. TOWS analysis is a method of strategic analysis, which involves a systematic and comprehensive assessment of the external and internal factors that determine the current competitive position and growth potential of a company [17]. This TOWS analysis concept can be used when sensing and screening business opportunities for better decision making. This can be better understood with the help of a description of the various components of the TOWS analysis in connection with company development.

The TOWS concept is closely related to SWOT analysis. Threats, Opportunities (in the environment) Weaknesses, Strengths (of the organization) should be analyzed in this order, as a sequence of problem solving in the strategy formulation process. TOWS analysis is a method of strategic analysis, which involves a systematic and

comprehensive assessment of the external and internal factors that determine the current competitive position and growth potential of a company [17]. This TOWS analysis concept can be used when sensing and screening business opportunities for better decision making. This can be better understood with the help of a description of the various components of the TOWS analysis with respect to enterprise development.

3 METHODOLOGY

This study was conducted through descriptive research. To obtain a complete and accurate description of a situation or event, research attempt to conduct descriptive studies. The research methodology used in this study is qualitative method with in-depth interviews. The technique of data collection is triangulated, data analysis is inductive, and the results of qualitative research emphasize meaning rather than generalization. Starting with looking and examining the existing theory about export processes in general and then deeper. In this study, researchers used data analysis techniques proposed by Miles & Huberman. Activities in analyzing qualitative data are carried out in an interactive way and take place continuously until the data is saturated. Activities in this data analysis includes data reduction, data display, and conclusion drawing/verification. Then, develop research questions based on the knowledge gained from reviewing the theory. After that, continue with collects data of firms' export strategy processes. After the data was collected and summarized, the comparison begins with the data and the theoretical predictions to conclude the applicability of the theory. Testing the validity of the data in this qualitative research method includes the credibility test, transferability test, dependability test, and confirmability test. Internal factors and external factors that affect company's export strategy will be analyzed by using 7S McKinsey, PESTEL and TOWS.

4 RESULT AND DISCUSSION

The company is mainly producing used cooking oil, which is processed with modern technology into a renewable energy source, namely biodiesel (bioenergy). Biodiesel is a safe and environment-friendly type of fuel, thus it reduces pollution in the environment. In the sales process of used cooking oil as the raw material for biodiesel production, the company has obtained a complete set of permits and certifications, especially ISCC. The company operates by procedures according to the international standards. The goal of the company is to provide tangible progress in the program planned by the government, Go Green and Go Health.

To achieve the desired production volume of used cooking oil, the company deploys marketing staffs to reach out to suppliers (door to door) for collaboration. When retrieving used cooking oil, the supplier may directly send it to the company's warehouse. In the process, there are also clear operational standards for the procedures which must be followed by the collection staff, such as wearing official uniforms, bringing delivery letter, recording petrol usage for the delivery vehicles, inspecting the quality of used cooking oil during retrieval, filling in retrieval forms and daily reports. These procedures are meant to maintain a good company image, as it offers professional service. Besides that, these daily reports are also used to monitor the amount of used cooking oil brought in. These data are then used by the company for annual ISCC audit.

The used cooking oil delivered into the warehouse will be checked again by the staff to ensure good quality. A simple check will be done by visually inspecting and smelling the aroma of the oil. If the quality of the oil is found to be below standards, a lab test will be done in the company's lab. Subsequently, oil with acceptable quality will be filtered using modern tools and stored in a storage tank. It will be scheduled for packaging into special polybags for export. Finally, the polybags will be loaded into containers and sent for export. In its business process, the company targets suppliers with large volumes of used cooking oil, such as food industries/factories, restaurants, hotels, SMEs (catering), and so on.

To analyze the company's internal environmental factors 7S McKinsey is used. This analysis has 7 main elements. The 7 elements must work in harmony if you want a company or organization to be successful in carrying out its activities as seen in Table I.

Based on the company's internal analysis using 7S McKinsey, currently the company is able to implement all 7 factors (strategy, structure, system, shared value, style, staff, and skill) well, as the activities done affects all those factors and have met expectations. One area of improvement is in systems, in which a centralized system that regulates the whole company is still absent. Besides that, other existing aspects shall also be improved in order for the company to excel in the industry.

Based on the PESTEL analysis as an external analysis, every factor, ranging from political, economic, social, technology, environment, and legal factors carries an impact towards the company, though with different level of significance. Factors with the highest level of significance include political, economic, and legal factors. Unstable politics will definitely affect the economy, which will be a threat for the company as it is coupled with a decreasing economic growth due to the COVID-19 pandemic. Legal factors are also still an issue, as no clear regulations by the government are made for this kind of business. Other factors such as environmental factors are positively affected; it helps reduce environmental pollution. The strategic current location of the company is one of its advantages.

Based on internal and external factors analysis using SWOT, the main strength of this company is its complete permits and certifications, especially ISCC which is the main criteria for export of used cooking oil. It helps increase consumers and suppliers' trust towards the company. The company also focuses to search for suppliers with mass quantity to maximize the collection process. In house marketing also helps suppliers to contact or locate the company, which is an important point to gain suppliers' trust. In addition, the company also has ISCC certificate, which is the requirement to enter the European market. With this ISCC certificate, all collection and sales are well-monitored, which also builds a good image of the company for consumers' trust. On the other hand, the absence of regulations regarding processing and disposal of used cooking oil is one of the company's weaknesses. The global pandemic also inhibits local companies in their business activities. Based on interview results, the recent ban for exporting used cooking oil implemented by the Chinese government regarding is seen as a great opportunity. The European market loses one of their suppliers, which means that it will actively search for another source in order to meet the demands for biodiesel production. Some threats for this company include

Table 1: 7S MC KINSEY

7S McKinsey Elements	Conclusion
Strategy	a. In accordance with the vision, mission, and goals
	b. Made for the short and long term
Structure	a. Functional Structure
	b. Managers, division heads, staff, work according to the job description and SOP
System	a. There is no main system that regulates the company
	b. The company system refers to the existing SOP
	c. SOP implementation at all management levels (managers, division heads, staff)
Shared value	a. There are 3 core values of the company: trust, integrity, quality control
	b. The most important core value of the company is trust
Style	a. The company's leadership style is democratic
	b. Tend to centralize to General Manager
Staff	a. Professional and experienced employee recruitment system
	b. The workforce is monitored based on daily reports and monthly evaluations
Skill	Every employee must have the ability to work together in teams.

the current global pandemic and the absence of regulation by the Indonesian government regarding the circulation of used cooking oil.

Based on the results of data analysis formulated using SWOT analysis, the strategies that have been implemented by the company include developing a direct source strategy where the company picks up used cooking oil directly to the supplier's place using their own fleet and staff (not using 3rd party services), this makes operating costs are cheaper, expanding the coverage area of the search for used cooking oil. After that, the company's alternative strategy was formulated using the TOWS Matrix, the following are recommendations for alternative strategies to be applied to the company as an additional strategy to expand market share and strengthen the company in competing in the used cooking oil collecting and exporting industry.

First, the chosen strategy is that the company expands its coverage area by reaching micro suppliers such as housewives, small traders and so on. Because so far the company has only focused on macro suppliers, namely suppliers with large volumes of used cooking oil, such as well-known outlets or restaurants, where during this pandemic, many outlets or large restaurants were empty of customers and reduced the volume of used cooking oil produced. Therefore, by reaching out to micro suppliers, companies can get additional volumes of used cooking oil.

Second, to expand the company, of course, adding workers to the marketing and collecting division which focuses on finding new suppliers, or outlets producing used cooking oil and consumers directly without any third party so that it is more reliable and saves operational costs. Where companies can take advantage of positive responses from the community regarding the company's concern for the environment to recruit workers who have concern towards the environment.

Third, companies can carry out pick-up activities, where companies can first offer their products to consumers using ISCC certificates as a guarantee for the quality of their products. By using the ISCC certificate, consumers will certainly be interested and consider the company's offers. So far, the company has only carried out pick-up activities for suppliers, where they offer binding contracts to suppliers.

Fourth, companies can modernize and digitize by doing digital marketing through online media, as well as developing applications related to their business processes so that they become more practical and can reach more suppliers and consumers.

Based on the results of the interview, another finding was found in the form of strength, namely the functional company structure for now due to the small number of employees so that each member plays a vital role and is a key for the company. Applying the principle of strong trust is one of the company's main values which is a strength for the company in convincing consumers, used cooking oil outlets and suppliers. There are also other opportunities, such as holidays and weekends where the use of oil is getting higher, such as in restaurants and other food industries. With this, automatically the volume of used cooking oil produced will increase and become a good opportunity for companies to obtain used cooking oil. Another finding is that other efforts are expected to reach outlets producing used cooking oil and households, namely by following modern technology where the company hopes that in the future a special application will be made as an intermediary in the used cooking oil business.

In reaching and expanding other areas for the collection of used used cooking oil, the Company must start looking for and multiply suppliers because with the increasing number of suppliers it has, then the expansion of the field of expansion of the coverage area of the search for used cooking oil to other areas is faster so that the volume of used cooking oil obtained can increase. However, it is also an important task for a marketer where marketing is one of the keys in the company because they are directly involved in convincing food industry outlets and suppliers to cooperate, so the company can continue to encourage marketing to have good performance.

The absence of clear regulations from the government regarding the collection, sales and export of used cooking oil can be a threat to the company's business processes. But even so, while waiting for regulations issued by the government, companies must continue

to run their business according to the rules that have been applied in the company, namely by always showing complete licensing documents and complete certification, especially ISCC certification, which makes the company trusted by other parties who wish to cooperate.

5 CONCLUSION

Company's strength lies in complete legality or complete licensing, good product quality, and a direct source strategy where the company in the collecting process does not use third parties. So the company must maintain this as an advantage compared to other competitors. In reaching and expanding other areas for the collection of used cooking oil, companies must start looking for and multiply suppliers because with the increasing number of suppliers they have, the expansion of the coverage area of the search for used cooking oil to other areas is faster so that the volume of used cooking oil obtained can increase. However, it is also an important task for a marketer where marketing is one of the keys in the company because they are directly involved in convincing food industry outlets and suppliers to cooperate, so the company can continue to encourage marketing to have good performance.

REFERENCES

[1] Indonesia Investments. 2019. *Minyak Sawit*. Retrieved from https://www.indonesia-investments.com/id/bisnis/komoditas/minyak-sawit/item166?

[2] Amara, Agatha Diora. 2021. *Mengenal Potensi dan Dampak Minyak Jelantah*. Retrieved form https://waste4change.com/blog/ringkasan-webinar-mengenal-potensi-dan-dampakminyak-jelantah/

[3] BKPM. 2022. *Harnessing Renewable Energy Investment Sector in Indonesia*. Retrieved form www.bkpm.go.id/en/publication/detail/news/harnessing-renewable-energy-investment-sector-in-indonesia

[4] Aprobi. 2022. *Aprobi for nations*. Retrieved from https://www.aprobi.or.id

[5] Fueleconomy. Retrieved from https://fueleconomy.gov/feg/biodiesel.shtml

[6] eubia.org. 2022. Used Cooking Oil – European Biomass Industry Association (eubia.org). Retrieved from https://www.eubia.org/cms/wiki-biomass/biomass-resources/challenges-related-to-biomass/used-cooking-oil-recycling/

[7] USDA. 2021. Oilseeds and Products Annual. Retrieved from https://www.oilworld.ru/data/postfiles/318617/Oilseeds-and-Products-Annual-Jakarta-Indonesia_03-15-2021.pdf

[8] EBTKE. 2020. Minyak Jelantah: Sebuah Potensi Bisnis Energi yang Menjanjikan. Retrieved from https://ebtke.esdm.go.id/post/2020/12/07/2725/minya.jelantah.sebuah.potensi.bisnis.energi.yang.menjanjikan

[9] Badan Pusat Statistik. 2021. Ekspor Desember 2019 Mencapai US$14,47 Miliar, sedangkan nilai impor mencapai US$14,50 Miliar. Retrieved from https://www.bps.go.id/pressrelease/2020/01/15/1734/ekspor-desember-2019-mencapai-us-14-47-miliar--sedangkan-nilai-impor-mencapai-us-14-50-miliar.html

[10] Parveen Ahmed Alam. 2017. Measuring Organizational Effectiveness through Performance Management System and Mckinsey 7S Model. *Asian Journal of Management* 8, 4 (Oct, 2017) 1280-1286. DOI: 10.5958/2321-5763.2017.00194.9

[11] Lusi Zafirana, Zainal Fanani, Indah Dwi Qurbani, and Sugiono. 2020. The strategy of developing palm-based biodiesel as energy resilience commodity using SWOT-ISM-BSC analysis. *International Journal of Advanced Science and Technology* 29,3. 6979 – 6995 Doi: 10.5281/zenodo.3613391

[12] P. D. Kremer and M. A. Symmons. 2015. Mass timber construction as an alternative to concrete and steel in the Australia building industry: A pestel evaluation of the potential. *International Wood Products Journal* 6, 3 (Jul, 2015) 138-147 Doi: https://doi.org/10.1179/2042645315Y.0000000010

[13] Jinbo Song, Jinbo, Yan Sun, and Lulu Jin. 2017. PESTEL analysis of the development of the waste-to-energy incineration industry in China. *Renewable and Sustainable Energy Reviews* 80, (Dec, 2017) 276–289. DOI: https://doi.org/10.1016/j.rser.2017.05.066

[14] Fachrul Herwanzah, Sagitha Devina Wijaya, and Rydho Jalu Nuringtyas. 2019. Marketing Strategy Analysis to Increase Competitiveness in National Ship Design Industry. *PEOPLE: International Journal of Social Sciences* 5, 1 (Apr, 2019) 420-429. DOI: 10.20319/pijss.2019.51.420429

[15] Marian Stuiver, Katrine Soma, Phoebe Koundouri, Sander van den Burg, Alwin Gerritsen, Thorbjørn Harkamp, Niels Dalsgaard, Fabio Zagonari, Raul Guanche, Jan-Joost Schouten, Saskia Hommes, Amerissa Giannouli, Tore Söderqvist, Lars Rosen, Rita Garção, Jenny Norrman, Christine Röckmann, Mark de Bel, Barbara Zanuttigh, Ole Petersen, and Flemming Møhlenberg. 2016. The governance of multi-use platforms at sea for energy production and aquaculture : Challenges for policy makers in European seas. *Sustainability 8*,4 (Apr, 2016) 333 Doi: https://doi.org/10.3390/su8040333

[16] Hanane Aghasafari, Alireza Karbasi, Hosein Mohammadi, and Roberto Calisti. 2020. Determination of the best strategies for development of organic farming: A SWOT e Fuzzy Analytic Network Process Approach. *Journal of Cleaner Production* 277, (Dec, 2020) 124039. DOI: https://doi.org/10.1016/j.jclepro.2020.124039

[17] Shobha Kulshrestha and Parul Puri. 2017. TOWS analysis for strategic choice of business opportunity and sustainable growth of small business. *Pacific Business Review International* 10,5 (Nov, 2017) 144-152. Retrieved from http://www.pbr.co.in/2017/2017_month/Nov/15.pdf

B2C E-Commerce Buyer Trust Measurement in Indonesia

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ABSTRACT

E-commerce has played a big part in the internet society. In this case trust is playing a big factor. The purpose of this research is to determine whether trust is a big factor in the recent decrease of the website traffic. The research will determine whether it is the main cause of the decrease of the website traffic or there is other factor that cause the decrease of the traffic.

CCS CONCEPTS

• **Computer systems organization** → Architectures; • **Information systems** → Data management systems; World Wide Web.

KEYWORDS

E-commerce, Website Traffic, Internet Society, Trust

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1 INTRODUCTION

E-commerce has played a big part in the internet society. In this case trust is playing a big factor. If there is less to no trust of people to a website or E-commerce, there will be no traffic on the website or E-commerce. In a physical store you buy, and you get the item. In E-commerce or online stores, you usually pay first then you get the item. In this case there is a need of trust between the user and the online store. That is why some of named e- commerce in which a lot of users have trust on them are trusting to pay before they get the item in their hand.

In the last 2 years the traffic of the Jardin website has been decreasing in which raising a question what the main cause of the declining of the website traffic are in which that are happened to the Jardin website. Is it trust issue between the user and the website or other factor that cause the decline of the website traffic?

The purpose of the research is to investigate is trust of the customer to the Jardin website is low or there is any other factor that are causing the decrease of the website traffic.

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Figure 1: The recent data of the declining of the website traffic.

2 RELATED WORKS

C2C or Customer to Customer E-Commerce system is a system where a customer selling product to another Customer in which they use an E-Commerce system to do so. In this case trust are based on two areas in which internal and external. Internal influences towards trust are usually the trust of the Customer toward the system or website that they are using. External influences are usually towards the seller or buyer or even third party.

Trust Level Measurement in this case is measuring the trust between customers on the E-Commerce on buying and selling products. What are the things that are concerning the customers? Some of the things that are concerning the customers are payment method. Usually when the payment method is using Joint Account or Cash on Delivery, the customers are not that concerned, and the trust level is higher. Payment method are one of the reasons of high trust level towards an **C2C E-Commerce. Some of the C2C** E-Commerce does not provide this, and this might be one of the reasons that the trust level of the E-Commerce is low. [3]

Internet has gone a very long way from the last few years. Nowadays customers do not need to go outside to a physical store to get the item they want to buy. E-Commerce is one of the options that people can choose so that they can shop while still at their houses. Trust is an important necessity on an E-Commerce in which plays a big factor on an E-Commerce running in the long term.

Trust can be divided into a lot of factors that influence it. One of them is the reputation of the E-Commerce vendor. By having high reputation, it can increase the believe of the customer that the seller is an honest one not a scam seller. The size of the E- Commerce also indicating that the vendor is an expert at the subject and is a big system which encouraging the trust of the customer on the product which they are selling. Multi-Channel Integration is the ability of the E-Commerce to have multiple communication towards the user. By having the ability to communicate easier to the user ensures the

user to use the E- Commerce system and increasing the trust level towards it.

System assurance in this case the system assuring the customer and the vendor in which the customer gets the item desired, and the vendor gets the money desired. In this case, the item is insured by insurance and the money is being held by the system which is the third party in this case. Having no assurance of the system may reduce the trust between the customer and vendor to the system. Customer willingness to buy an item through E-Commerce in this case will be towards the Customer's trust in the E-Commerce system. Risk perception is a negative on a trust level. Customer's perceived risk might or is the main reason for a negative trust level in using the E-Commerce system. One of them might be the risk of the vendor being a scam or the willingness of the customer to buy in the E-Commerce. [3]

Jardin is an online official retailer branching from the PT. Jardin Traco Utama which is centered in North Jakarta. Jardin has stood and run physical gold trading since 1986. Jardin also provides e-commerce website and online store in multiple marketplaces like Tokopedia, Shopee, Lazada, and others which makes shopping precious metal easier than ever.

Jardin also worked together with multiple logistic companies that are trusted in delivering precious metals. And Jardin also prioritizes the safety of the packages that are being sent by using the standardized packaging so the package is safe so we can avoid any unwanted things happening to the product**.** **[**4]

3 METHODOLOGY

To gather the data for this research questionnaire is being spread towards the user of Jardin and outside of Jardin. The questionnaire is made by google form. In which is being spread towards the user through WhatsApp, e-mail, Facebook, and marketplace chat.

This data is used to answer the research question and the validation of the data that are collected from the research. Which, the process of primary data collection is using a questionnaire.

The questions which are being asked are used to determine the user trust level towards the website or the platform being used.

These questions are going to address the research objective. The questionnaire will be put in Google Drive which will determine the validity of the data of each user's trust level. After the questions are answered, it's time to review each of the data that have been inputted.

3.1 Unit of Analysis

The unit of analysis is the person who is constructing what is being studied or the person who is being studied. The unit that is being analyzed can be either individuals or groups. For the unit analysis, the data is needed to be collected and applied to the research. Therefore, the unit being analyzed and studied needs to be the customer of the Jardin that does transactions within or outside the marketplace.

3.2 Population and Sample

The target audience is either the individual or the activity that the researcher is interested to. The population of the research will be the customer who buy and sell gold. To narrow down the target population of the research it only be the customer who does the transaction in the marketplace or website.

Type of sampling used for this research is the non- probability sampling. Non-probability sampling is a sampling technique in which the researcher selecting the sample that are based on the subject that the researching is doing research on. This sampling will be more focused on the subject being researched.

For the high accuracy of the research study, a confidence level of 95% is needed in which the margin of error of maximum 5% is being applied to the research. Below is the formula to determine the minimum number of respondents for the research.

$$n = \text{Numberof Statements} \times 5n = 10 \times 5$$
$$n = 50$$

Therefore, the minimum respondents needed for this research is 50 respondents. The purpose of this research the goal to get 50 respondents for more constructive data for the research. In which the confidence level of this research is 95% and the maximum margin of error is 5%.

Data Collection Method is referring to the means of getting the information, test the hypothesis, collecting and assess the result from the data that have been collected. This research will gather information from online research which consists of paper, books, previous thesis with similar topics and an online questionnaire to collect new data. The online research is being used to collect the Secondary Data whereas the online questionnaire is used to collect the primary data from the customer of the online store. This questionnaire is designed to measure the variables that are distributed towards the customer of the Jardin online store, whether they do transaction in the marketplace like Tokopedia or through the Jardin website at least once and the customer of Jardin that are buying by walking into the physical store.

The questions in the questionnaire will be scaled by using Likert Scale by asking the specific question towards the problem rising in the Jardin website. This might express favorable or even unfavorable attitude toward the subject. The respondent of the questionnaire will be asked whether they agree or disagree with the statement given in the questionnaire. The question that are available in the questionnaire will be scored using 5 points of Likert Scale. In which the example of Likert Scaled used is like the table shown below:

4 RESULT

The Questionnaire was held from March 14 to 3 June 2022. In this case there is 56 respondents that have responded to the questionnaire that have been distributed during the time using google form. That is still good considering the minimum sampling is 50 samples.

To measure the variables being studied, the data are being collected are measured in an application called IBM SPSS Statistics and IBM SPSS AMOS. In this case, SPSS is used to calculate the mean, standard deviation and correlation matrices of the data that are collected from the questionnaires.

The Questionnaire is divided into several part in which will help in collecting data for the research. These part's objectives are to give an insight into the trust level of the customer to the Jardin website. The respondents come from the Jardin in the marketplace, walk-in to the store, and other potential customers. The reason of picking the respondents is to determine the main reason of the

Table 1: Likert Scale

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Table 2: Demographic Profile of Respondents

		Number
Gender	Male	34
	Female	22
Age	< 23	1
	23-35	37
	> 35	18
City	Jakarta	23
	Tangerang	12
	Bekasi	6
	Bogor	5
	Others	10
Education Level	SD	0
	SMP	0
	SMA/SMK	11
	S1	42
	S2	2
	S3	0
Daily Internet Usage	< 4	10
	4 to 7	19
	8 to 10	3
	> 10	5

avoidance of the customer and potential customer of using the Jardin Website.

4.1 Demographic Profile of the Respondent

The profile of the respondents is shown the Table 2. The sample consists of 56 valid responses. The gender of the respondent's majority are males in which they are 61.8% compared to 39.2% of the female respondent. Most of the respondents are relatively young as they were mostly between 23 to 35 years old. Most of the respondents are also well educated as they mostly finish their bachelor's degree on their studies. And most of the respondents are mostly living in big cities like Jakarta and Tangerang in which indicates the bigger possibility of using the internet on their daily life. In which can be seen in the table that the daily internet usage is pretty much the daily average of the one living in the big cities because of the availability and environment.

Table 3: Respondent Experience using E-Commerce System in Indonesia

		Number
Have you ever done transaction in Indonesian E-Commerce website?	Yes	56
	No	0
What is the price range of the items that you have purchased from E-Commerce website in Indonesia?	Rp. 50.000 - Rp. 500.000	0
	Rp. 500.000 - Rp. 1.500.000	7
	Rp. 1.500.000 - Rp. 5.000.000	27
	Rp. 5.000.000 - Rp. 10.000.000	7
	Rp. 10.000.000 - Rp. 30.000.000	9
	> Rp. 30.000.000	6
Payment method used in E-commerce	Bank Transfer	18
	Credit Card	10
	Electronic Money: Gopay/OVO/Dana/ShopeePay/Alipay	28
	Cash on Delivery	0
	Others	0

4.2 Respondent Experience using e-commerce system in Indonesia

Table 3 shows that all our respondents have used and to transaction on Indonesian E-Commerce website. Most of the respondents' answers that the price range of the item that they ever bought from E-Commerce website in Indonesia is from Rp.1.500.000 to Rp. 5.000.000. And only a small amount of respondent ever bought item more than Rp.30.000.000 from an E- Commerce website. Most of the respondents are using Electronic Money as their primary payment method in which is very popular nowadays because of a lot of promotion that comes while using Electronic Money that entice the user more to use it.

Table 4: Means, Standard Deviation and Correlation

Variable	Mean	SD	1	2	3	4	5	6
1. Gender	1.43	.54373	-	-	-	-	-	-
2. Age	2.28	.50168	-.134**	-	-	-	-	-
3. Customer Satisfaction	2.29	1.15887	.036**	-.172**	-	-	-	-
4. Price	1.10	.70642	.279**	-.025**	.142**	-	-	-
5. Willingness to Buy	1.19	.74891	.386**	-.032**	-.124**	.67	-	-
6. Trust	1.41	.80487	.342**	-.020**	.056**	.47	.674**	-

**. Correlation is significant at the 0.01 level (2-tailed)

Table 5: Collinearity Statistics

Independent Variable	Tolerance	VIF
Gender	0.834	1.200
Age	0.952	1.051
Customer Satisfaction	0.948	1.054
Price	0.543	1.841
Willingness to Buy	0.503	1.988

4.3 Means, Standard Deviation and Correlation Matrices

Table 4 showing the mean, standard deviation, and correlation of the construct variable. Multi-collinearity can be considered a problem only "if the correlation coefficient between two values of two regressors is greater than 0.8 or 0.9" according to Judge et al [1]. The correlation between the variables is below 0.8. In this case there is no multi-collinearity between the variables in the Table.

Teo's [2] study indicates that calculating of Variance Inflation Factor (VIF) should be independent so it can be an indicator for the multicollinearity. Having a large VIF value indicating a possible multicollinearity between the variables. Result from the table 5 of Collinearity Statistics indicates that the independent variable has VIF with the value less than 2.0. Which means that there is no multi-collinearity problem among the independent variables in the research.

4.4 Structural Equation Modelling

SEM is an extension of GLM (General Linear Model) that is used to test regression of equations simultaneously. The purpose of SEM is to examine the relationship between independent variables and dependent variables.

SEM is conducted using SPSS Statistic and SPSS AMOS. Which is based on the research model, Confirmatory Factor Analysis (CFA) that is being used in this research. CFA is used for collecting the value of the variable from the construct.

SPSS Statistic is used to determine the covariance between the variables in the data that are collected during the research, and AMOS is used to determine the fit indices of the data presented by the Statistic.

In table 7 the value of the fit indices of AGFI, NFI, TLI, and CFI are not that far apart compared to the recommended value of the fit indices. And the GFI of the fit indices value is above recommended value which is 0.9.

Table 6: Construct Rability Analysis

Construct	No. of items	Composite Reliability	Variance Extracted
Customer Satisfaction	3	0.990	0.970
Willingness To Buy	4	0.838	0.638
Trust	2	0.911	0.837

Table 7: Fit Indices Table

Fit Indices	Rec. Value	Value
Chi-square	Smaller Value	441.957
df	Smaller Value	20
p	< 0.05	< 0.05
GFI	> = 0.9	0.901
AGFI	> = 0.9	0.753
NFI	> = 0.9	0.763
TLI	> = 0.9	0.734
CFI	> = 0.9	0.841
RMSEA	< = 0.08	0.166

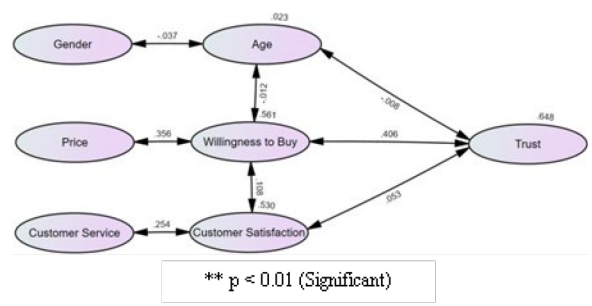

Figure 2: Strucutral Equation Model of the Research

The Structural Equation Model result indicates that the fifty-six of the respondents during the time are indicating that the trust level between customers towards Jardin is 64.8%. This also accounted with the willingness to buy which is 56.1% following by 53% of customer satisfaction. So, the customer trust SEM can be used to explain the large value of the variance in the Customer Trust, Willingness to Buy and Customer Satisfaction towards Jardin.

5 DISCUSSION

From the result, we can see the trust level of the customer to the website system. That being the value of 64.8% means that the trust level of the customer of Jardin are relatively positive towards the Jardin website. This positive trust level achieved from Customer Satisfaction and Willingness to Buy that helps in boosting the trust level of the customer towards the Jardin website.

In this case we can compare to similar study that is being conducted in Indonesia, the trust level of Indonesia customer towards the E-Commerce system is 66% in which almost similar compared to the trust level measurement during the research in these few months. In another study, which compares to the United States, Singapore, and China's trust level towards E-Commerce, Indonesia's trust level is the lowest. In which the customer in United States has 80% trust level, Singapore with 77% trust level, and China with 76% trust level towards the E-Commerce system.

Based on the result, Age is not related to customer's trust level towards the Jardin website. Since both have negative relation towards each variable. Customer trust is positive related to the willingness to buy and the customer satisfaction. This means that the more the customer satisfied with the service they might have had during transaction or from other customer's recommendation, shows positive result towards the Customer Trust to the Jardin Website. And the willingness of the customer to buy the product because of the price which is a small factor but still influence the customer to do transaction towards Jardin.

In conclusion, from the research that have been made during these past few months the trust measurement level towards the Jardin Website is 64.8%. The things that influence which is positively related to the trust level are Customer Satisfaction and Willingness to Buy. Customer Satisfaction shows and the Willingness to Buy shows positive value towards the Customer Trust to the Jardin Website. The more of the customer trust towards the Jardin website the more the customer willingness to buy. And the more positive value towards Customer Satisfaction the more the trust of the customer towards the Jardin Website.

6 CONCLUSION AND RECOMMENDATION

After doing the research there are possible further studies that can be done. The first one is to do research towards marketing strategy on the Jardin Website which is not taken yet on the research. The second one is the payment method affect towards the Customer Trust level towards the Jardin Website. Even though it is taken from the questionnaire, it is needed to do a more detail research towards these variables. Quantitative research is needed to further measure the Trust Level of the customer towards the Jardin Website and further look for the declining of the Jardin Website in these past two years.

I would like to thank my family for giving me the support and both of my Advisor Mr. James Purnama and Co-Advisor Mr. Kho I Eng who have helped me to give the idea of the research topic. And for the advice during the writing in these few months.

REFERENCES

[1] H. R. Griffiths W Lutkepohl H Lee TC. Judge GG, Introduction to the theory and practice econometrics, Wiley, 1982.
[2] J. T. S. Teo, Consumer trust in e-commerce in the United States, Singapore, and China, The International Journal of Management Science, 35, 2005.
[3] J. P. M. A. A. S. M. G. Sayid Ali Hadi, "C2C E-Commerce Trust Level Measurement and Analysis in Indonesia," p. 6, 2014.
[4] J. P. M. A. A. S. a. M. G. Bimo Harsandi, "Internet User Trust Measurement Analysis Towards ECommerce System in Indonesia," 2013.
[5] Jardin, "Jardin," [Online]. Available: https://www.jardin.co.id.
[6] Wikipedia, "Variance Inflation Factor," [Online]. Available: https://en.wikipedia.org/wiki/Variance_inflation_factor.

Inventory Level Reduction with VMI and Internet of Things Method

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ABSTRACT

PT. XYZ is a company focusing on producing herbal beverages in glass bottles. Inventory level is an important aspect and needs to be controlled by PT. XYZ because it has a strong relationship with the company's cash flow. At this moment, the average inventory level for the glass bottle of PT. XYZ is 32 days, while the target inventory level of the glass bottle must be achieved by PT. XYZ is 14 days. This research will focus on reducing the inventory level of glass bottles in PT. XYZ and ensure the supply sustainability in a high service level. Reduction of inventory level in PT. XYZ can be achieved by implementing the Internet of Things (IoT) and the Vendor Managed Inventory (VMI) method. VMI method implementation will focus on the stock availability with a low inventory level, and the implementation of the Internet of Things will make the inventory level information can be accessed in real-time and resolve this inventory problem. After improvement had been conducted, the service level (vendor performance) of glass bottles increased from 65% to 95%, and the inventory level reduced from 32 days of inventory (DOI) to 9 days.

CCS CONCEPTS

• :; • **Applied Computing – Operations Research – Industry and Manufacturing – Supply Chain Management**;

KEYWORDS

Manufacturing system, Supply Chain, Inventory level, Vendor Managed Inventory, Internet of Things

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1 INTRODUCTION

PT. XYZ is one of Indonesia's Fast Moving Consumer Good (FMCG) companies focusing on herbal beverage production in glass bottles. In order to support PT. XYZ production and creating an adequate inventory level is an essential aspect. Optimal inventory level determination helps a company to achieve service level in production, decrease inventory level and reduce costs such as operating cost and inventory cost [1]. Currently PT. XYZ has a problem where the actual inventory levels do not meet PT. XYZ target. The target inventory level of PT. XYZ is 14 days of inventory, but the actual inventory level is 32 days. The problem of high inventory level is an essential aspect to resolve because of the top management of PT. XYZ decided to improve company cash flow as soon as possible. The main reason for high inventory level is caused by high minimum delivery quantity (MDQ), high minimum order quantity (MOQ), and low service level by the vendor (supply shortage).

In addition, PT. XYZ has set a minimum of 90% as a target for vendor service level, while the current service level of vendor is only 65%. The low service level shows that vendor is unable to send the raw material on time and in the correct quantity. The vendor has many obstacles, such as long order and delivery lead time, container shortage, and frequent schedule changes by PT. XYZ, while PT. XYZ has a single vendor policy. The step was taken by PT. XYZ overcame this problem by raising their inventory level to ensure all glass bottles are ready to use, but this approach still cannot help PT. XYZ to reach the target service level while creating a higher inventory level that impacts to company's cash flow.

The complexity of the problems faced by PT. XYZ requires the appropriate method, so the problem of high inventory levels and low service levels at PT. XYZ can be solved, and the existing costs can be allocated for other essential needs without disrupting the production process due to problems with the availability of glass bottle materials. One of the most appropriate methods to overcome the problems of PT. XYZ is by applying the Vendor Managed Inventory (VMI) method. This method is a strategy of cooperation and coordination between the vendor and the company so both parties can benefit simultaneously [2].

Another study also describes Vendor Managed Inventory (VMI) as a system where the factory or vendor monitors and controls customer needs. The vendor will be responsible for delivering the product in the correct quantity and time so that there is no stock out, which can impact the customer service level [3]. Several studies have discussed decreasing inventory and increasing service levels by applying the VMI method. The VMI method has been applied to the distribution center and the retail industry in East Asia, which

can overcome the problem of vehicle types and solve the problem of demand and inventory [4]. In addition, the implementation of the VMI method in the construction industry also helps reduce inventory levels by 70% [5]. The VMI method applied to the shipping logistics industry can also help provide a financial impact for companies that can significantly reduce shipping costs [6]. From the research that has been done previously, no research discusses the reduction of the inventory level of glass bottles in the beverage industry. In addition, no other study combines VMI with the Internet of Things in reducing inventory levels. The Internet of Things approach will assist the stock monitoring process in real-time to support the applied VMI method. This feature is essential for PT. XYZ often changes its production schedule and glass bottle delivery schedule. In addition, the stock-taking process can be minimized because real-time, quick, and accurate information is available between PT. XYZ and vendor. Thus, the process of distributing information between PT. XYZ and the vendor will run smoothly.

Reducing inventory levels is crucial because enormous costs have been spent on high inventory levels, which can be allocated for other more essential purposes [7]. In addition, the results of this research can be implemented in other manufacturing industries engaged in food and beverage production.

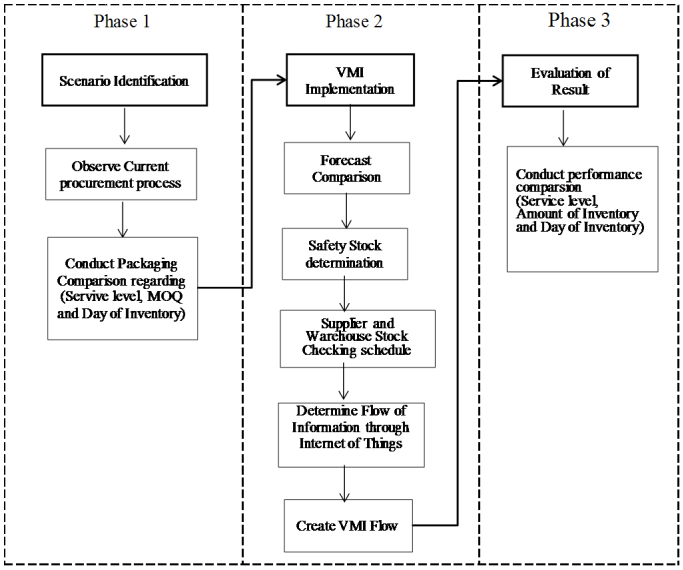

Figure 1: Research Methodology

2 RESEARCH METHODOLOGY

2.1 Phase 1

In this phase, the initial information collection is conducted. At this phase, the categories and types of goods that will be the research focus are determined. After the data is obtained, all the constraints in the procurement process are determined. This process also determines what costs may arise in the product procurement process. In the end, the inventory level and service level measurement process will be assessed. All phases of the research methodology are summarized in Figure 1.

2.2 Phase 2

The second phase is the VMI implementation process. In the early stages of this process, forecast data will be the primary consideration in determining the number of bottles needed from bottle vendors. This step is essential and is the critical success of VMI implementation [8]. At this stage, several forecasting methods will be applied to determine the amount of demand, such as the Moving Average, Holt, and winter methods. Determining the forecast figure is crucial because it becomes the basis for determining the total amount of purchases [2]. The next step is determining the stock limit used as a joint reference between PT. XYZ and vendors. This condition will help to improve performance with constant vendor lead-time conditions [9].

The next process is to determine the frequency of joint stock-taking to ensure the inventory level of PT. XYZ according to the agreement. This stage is essential because unclear information will impact the smoothness of this method [10]. If the stock level is not lower than the stock limit, then the vendor does not need to implement the replenishment process. Every day there will be a process of providing information from PT. XYZ to the vendor regarding the amount of daily consumption and the remaining available stock. This step will help reduce customers' ordering activity and minimize the information and delivery delay. The vendor gets information about transactions that occur with customers, so that vendor can process this information to implement customer replenishment activities [11]. This information will be used as a reference for glass bottle vendors for the billing process. All information will be distributed in real-time with the Internet of Things (IoT) approach, making it easier for all parties. Internet of Things implementation can reduce the need for direct human involvement and intervention that may affect human error [12]. IoT will help perform complex or repetitive tasks suitable for PT. XYZ case [13]. IoT implementation can also be aligned with VMI implementation, with implementation details referring to Figure 2. The roles of each party are explained as follows [14].

- Customers: interact with vendors via system, place orders or let vendors manage their resources
- Delivery service: providing delivery according to some parameters defined in the smart contract or determined by the quality policy.

2.3 Phase 3

In this phase, a performance comparison will be made between the process before and after implementing the Vendor Managed Inventory and Internet of Things. Through the implementation of this method, it will be determined whether there is an increase in the inventory level and vendor service level, whether the target inventory level can be achieved, and how the proposed process influences the vendor's service level.

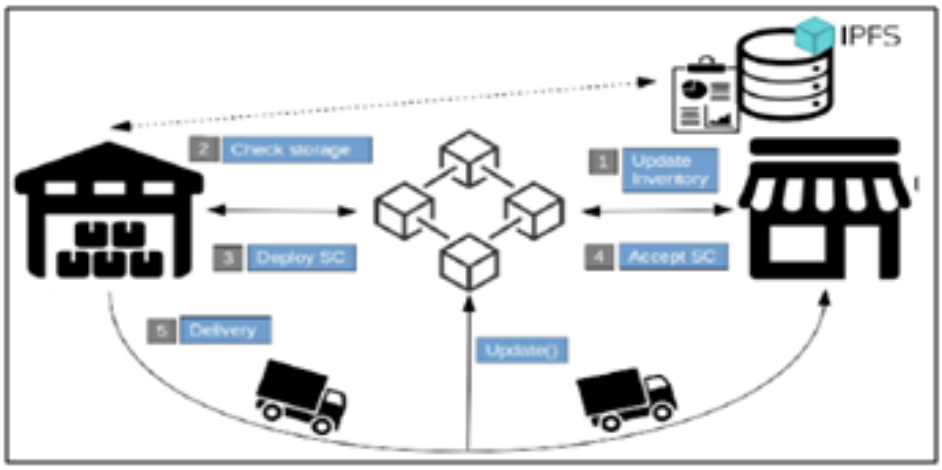

Figure 2: Block chain-based VMI overview [14]

Table 1: Packaging Comparison

Packaging	Service level	MOQ (thousands)	DOI (days)
Glass bottle	65%	3,800	32
Cap	75%	410	14
Sleeve	95%	75	17
Carton box	88%	23	3

3 VMI AND IOT IMPLEMENTATION

3.1 Phase 1

Categories and types of goods that will be the research focus are determined. The Total Amount Purchase (TAP) is the initial consideration in determining the product category. Based on Total Amount Purchase (TAP) data for the last two years, it was found that the packaging material category contributed 45% of the total purchased, followed by the raw material category at 37% and the supporting material category at 18%. Based on the data above, it can be concluded that packaging material has the highest TAP compared to other categories and will be selected as the focus of this research. In the next process, four types of packaging materials are compared to decide which type of packaging product will be selected as the main focus of this research. Service level, minimum order quantity (MOQ), and inventory level or days of inventory (DOI) between types of packaging are compared, referring to Table 1. Therefore, glass bottles with the lowest service level, the highest MOQ, and DOI will be selected as the focus product to be assessed in this research.

3.2 Phase 2

In the next stage, the forecast method is determined. At this stage, a running forecast is made, which will be given to the vendor as the primary consideration for preparing the raw material that the vendor must prepare to meet PT. XYZ needs. In order to select the best type of forecasting method, four methods are carried out in the processing: the TSD method, Moving Average (MA), Holt's, and Winters. The forecast accuracy values compared are MSE, MAPE, MAD, and TS [15]. Based on the results of data processing, by comparing the forecast accuracy values (MSE, MAPE, MAD, TS), it is obtained that the moving average two forecast methods are the most suitable forecasting method for PT. XYZ bottles with the smallest error percentage. The forecast data demand is shown in Figure 3.

The next step is determining the stock limit (safety stock) as a reference between PT. XYZ and the vendor to ensure the availability of the glass bottle. Determination of stock limit is an essential aspect as the basis for replenishment number that will be used as a reference. The amount of this reorder point must consider many factors such as minimum delivery quantity (MDQ) of vendor and warehouse capacity. With this reference, the vendor must conduct the replenishment process referring to the agreed quantity.

The next step is the calculation of the safety stock that will be carried out using the approach made by Scheilder & Workman in 2009 16, where the safety stock is obtained from the formula below

$$SafetyStock = SafetyStockDemand + SafetyStockSupply + SafetyStockstrategic \quad (1)$$

$$SSDemand = (1 - -forecastaccuracy)\ xleadtime \quad (2)$$

$$(1 - 60\%)\ \text{x7days} = 2.8\text{daysofcoverageneeded}$$

$$\text{SSSupply} = (1 - -\text{forecastvendorservicelevel})\ \text{xleadtime} \quad (3)$$

$$(1 - 65\%)\ \text{x2days} = 0.7\text{daysofcoverageneeded}$$

$$\text{SSStrategic} = \text{daysofcoverageneeded} \quad (4)$$

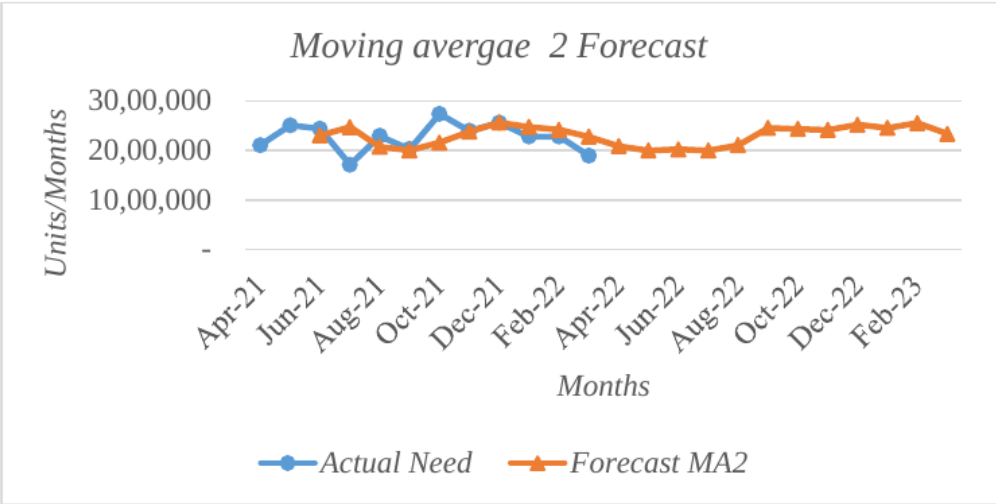

Figure 3: Forecast Moving Average 2

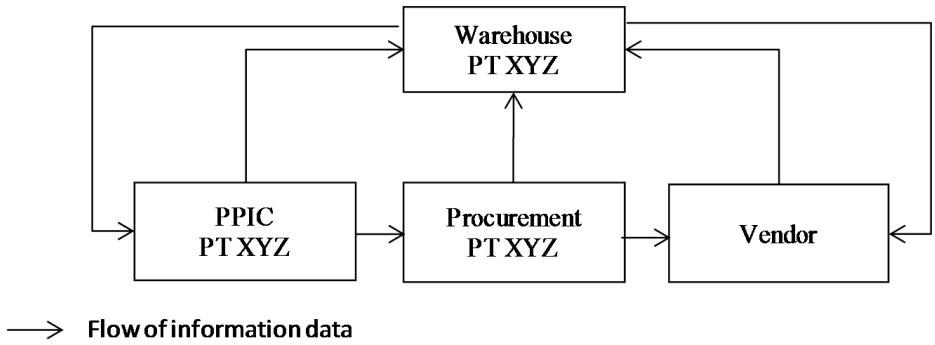

Figure 4: IoT – Flow of Information

= 2daysofinventory

SafetyStock = 2.8 + 0.7 + 2days = 5.5 = Roundup = 6Daysofcoverageneeded

6daysSafetyStockx160.000pcs = 960.000pcs

The next process is determining the stock-taking frequency to ensure PT XYZ's inventory level follows the agreement. Previously stock tacking and the assessment score were collected manually, and the stock-taking was conducted twice a month. After the implementation of VMI and the Internet of Things, stock-taking is conducted monthly, on the 10th of every month. PT. XYZ warehouse team will conduct the stock-taking process independently, and the data will be updated in real-time by PPIC and the warehouse team so that all parties can identify stock data and shortage events can be detected. IoT implementation will help all remaining stock is up to date in real-time. Monitor with PLC will be provided so that the Warehouse department can distribute all the remaining stock information to all divisions. All flow information is explained in Figure 4 and 5. All information shown in Figure 5 is essential information for the vendor and the warehouse department to ensure all the replenishment processes will be conducted at an appropriate time, and the vendor also noticed if there is defect product in their products.

If the stock level is not lower than the stock limit, then the replenishment process does not apply by the vendor so that it can reduce the amount of inventory PT. XYZ. Every day there will be a process of providing information from PT. XYZ to the vendor regarding the number of daily usages and remaining available stock the date of use. This information will be used as a reference for glass bottle vendors for the billing process. All information can be accessed in real-time with the Internet of Things approach, making it easier for all parties

The next process is determining the Economic Order Quantity (EOQ). This method is selected in this order to reduce possible costs from the holding, order, and other costs. This EOQ application is implemented so that the company's financial and operational aspects can reach the optimal point. Therefore the total amount of

Detail		
Day		
Number of Shift		
Time		
Name of Product		
Filling Speed		Bottle/hour
Infeed Bottle		Pcs
Reject Bottle		Pcs
Output		Pcs
Estimate Output		Pcs
Bottle Stock		Pcs

Figure 5: Information Interface

Table 2: Before and after implementation comparison

Detail	As is	To be
Service level	65%	95%
Inventory (thousand)	3,800	1,329
DOI (days)	32	9

production is 15:

$$Q = pt_1 \Rightarrow t_1 = \frac{Q}{p} \tag{5}$$

$$t_1 \; is : (p - r)\, t_1 = (p - r)\, Q/p = Q\,(1 - r/p) \tag{6}$$

$$\text{Thereforetheaverageinventoryis} = \frac{1}{2} Q\,(1 - r/p) \tag{7}$$

$$\text{Thustheinventorycarryingcostis} = \frac{1}{2} Q\,(1 - r/p)\, C_h \tag{8}$$

$$\text{Theorderingcost (asbefore) is} = \frac{D}{Q} C_o \tag{9}$$

$$\text{Thusthetotalcostis, TC} = \frac{1}{2} Q\,(1 - r/p)\, C_h + \frac{D}{Q} C_o \tag{10}$$

Therefore, differentiating expression (5-10) with respect to Q,

$$\frac{d\,(TC)}{dQ} = -\frac{D}{Q^2} C_o + \frac{1}{2} C_h\,(1 - r/p) \tag{11}$$

$$\begin{aligned} Q &= \frac{\sqrt{2DC}}{((CH)\left(1 - \frac{R}{P}\right)} = \frac{\sqrt{2 \;\boldsymbol{x}\; 2{,}341{,}869 \;\boldsymbol{x}\; 100{,}000}}{((2)(1 - 200{,}000/300{,}000)} \\ &= 725{,}839 \text{pcsbottles} \end{aligned}$$

All sequence of VMI implementation is shown in Figure 6.

3.3 Phase 3

In this phase, a performance comparison will be made between the process before the implementation of the vendor managed inventory and after the implementation. With the application of this method, it will be determined whether there is an increase in the inventory level, whether the target inventory level can be achieved and how the proposed process influences the service level of the vendor are shown in Table 2.

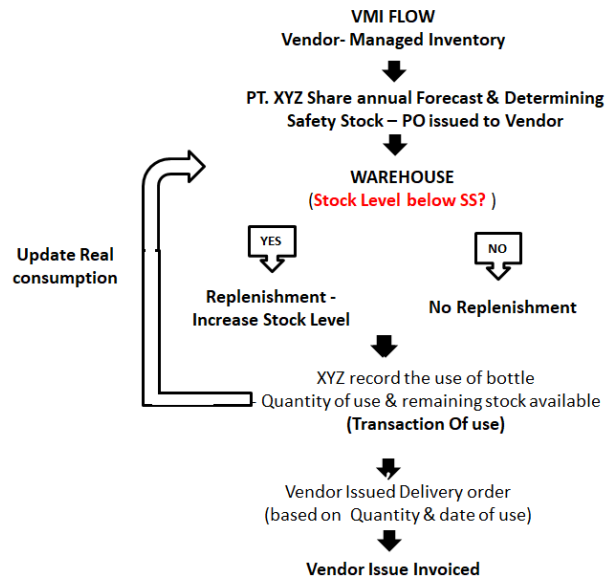

Figure 6: Vendor Managed Inventory Flow

4 CONCLUSION

After implementing the VMI method and the internet of things in June 2022, it is shown that there is an improvement in glass bottle vendor service level (delivery) by about 30% and a reduced inventory level from 32 days of inventory (DOI) to 9 days. Furthermore, it can be proposed in the future for the PT. XYZ should also implement the VMI method and internet of things in other product categories, such as raw material and supporting category, so all product category service levels & inventory levels can be improved in the future.

REFERENCES

[1] Watheq Hayawi Laith, S. S.-Z. 2018. Determination Optimum Inventory Level for Material Using Genetic Algorithm. Journal of Engineering, pp. 218-230.
[2] David Simchi-Levi, E. S.-L. 2000. Designing and Managing the Supply Chain : Concepts Strategies, and Case Studies. New York: McGraw-Hill.
[3] Dewi, F. R., & Garside, A. K. (2015). Reducing Bullwhip Effect with Vendor Managed Inventory Method. Journal of Industrial System Optimization, Vol 14,pp. 292-298.
[4] Annarita De Maio, D. L. 2020. The effectiveness of Vendor Managed Inventory in the last-mile delivery: an industrial application. Arcavacata: Procedia Manufacturing. International Conference on Industry 4.0 and Smart Manufacturing (ISM 2019) pp. 462–466.
[5] Kari Tanskanen, J. H. 2008. Vendor-managed-inventory (VMI) in construction. International Journal of Productivity and Performance Management, pp. 1-15.
[6] Magnus Stålhane, H. M. 2015. Vendor managed inventory in trampshipping. Omega Vol 47, pp. 60-72.
[7] Ellison, P. B. 2020. Health economic analysis of pharmaceutical inventory levels. Journal of Humanitarian Logistics and Supply Chain Management, pp 1-26.
[8] Sule BİRİM, C. S. 2017. EVALUATING VENDOR MANAGED INVENTORY SYSTEMS HOW INCENTIVES CAN BENEFIT SUPPLY CHAIN PARTNERS. Journal of Business Economics and Management, pp. 163–179.
[9] Sari, K. 2007. Exploring the benefits of vendor managed inventory. International Journal of Physical Distribution & Logistics Management, pp. 529-545.
[10] Roba Walid Salem, A. E. 2017. Vendor Managed Inventory (VMI): From Theory to Practical Implementation A Literature Review. Int. J Sup. Chain. Mgt, pp. 68-92.
[11] Xianpei Hong, W. C. 2016. Multiple-vendor, multiple-retailer based vendor-managed inventory. Annals of Operations Research, pp. 1-22.
[12] Georgios Lampropoulos, K. S. 2018. Internet of Things (IoT) in Industry: Contemporary Application Domains Innovative Technologies and Intelligent Manufacturing. International Journal of Advances in Scientific Research and Engineering

(IJARSE), pp. 109-118.
[13] F. Alarcón, D. P. 2016. Using the Internet of Things in a production planning context. Brazilian Journal of Operations & Production Management, pp. 72-76.
[14] Tom Dasaklis, F. C. 2019. Improving Vendor-managed Inventory Strategy Based on Internet of Things (IoT) Applications and Blockchain Technology. International Conference on Blockchain and Cryptocurrency (ICBC) Seoul: IEEE, pp. 50-55.
[15] Bandyopadhyay, S. 2019. Production and Operations Analysis Traditional, Latest, and Smart Views. New York: CRC Press.
[16] Lisan, S. 2018. Safety Stock Determination of Uncertain Demand and Mutually Dependent Variables. International Journal of Business and Social Research, pp. 1-11.

E-Commerce Platform Service Improvement of PT. X Based on Multiple Approach Integration

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ABSTRACT

The study was conducted at PT X, a service provider that uses an e-commerce platform to enable transactions between buyers, tenants, and property agents using an e-commerce platform. In-depth conversations with the management have led PT X to the realization that it lacks integrated and measurable information on the types of e-commerce platform service functions that need to be addressed in light of the functional and emotional needs of its customers. The study's primary goal is to establish priorities for enhancing the services provided by PT X's e-commerce platform. The study methodology was focused on the integration of several approaches, including Kansei engineering, service blueprints, Kano model, Theory of Inventive Problem Solving (TRIZ), and others. The findings demonstrated that there are one basic functional indicator and three one-dimension functional indicators are the service indicators of PT X's e-commerce platform that need improvement most urgently. Based on the results, improvements to the working mechanism were proposed, such as the development of training modules for employees; offering intensive training programs for employees, improving standard operating procedures, creating work instructions, and perfecting service level agreements and others to address customer complaints about the usage of PT X's e-commerce platform.

CCS CONCEPTS

• **General and reference** → Document types; Surveys and overviews; • **Social and professional topics** → Professional topics; Management of computing and information systems.

KEYWORDS

Service, Service Blueprint, E-commerce Service, Kansei Engineering, E-Service Quality, Kano Model, TRIZ

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1 INTRODUCTION

The service industry is expected to become the driving locomotive of a nation's economy in the present and future. The service industry has aided the expansion of numerous service-related businesses. Service encompasses all economic activities whose result is not a physical product but yet provides added value in various forms, such as convenience, entertainment, comfort, or health [1].

Since its establishment in 2019, PT X has become a pioneer company in terms of creating an e-commerce platform that can be used to sell, buy, and rent properties. PT X's e-commerce platform has helped a lot to bring together the interests of multi-stakeholders, such as: owners, buyers, tenants, and property agents. Through this e-commerce platform service, PT X has enabled customers or multiple parties to carry out the process of buying and selling and renting property more easily, quickly, and transparently. However, in the last regular evaluation, it was found that there were still some complaints from customers which indicates that customers are not satisfied with the performance of PT. X. In addition, through structured and in-depth discussions with top management, PT X realized that it did not yet have a top priority for e-commerce platform services. Priority information on e-commerce platform service upgrades will really lower the number of consumer/customer complaints, raise loyalty satisfaction among consumers/customers, and enhance service competitiveness continuously in the targeted market [2]. Therefore, the focus of the study is directed at how to improve the service performance of PT X's customer service work unit which manages the e-commerce platform.

For the improvement of e-commerce platform services, the main objectives of this study are to: (a) identify the functional and emotional needs of customers related to PT X's e-commerce platform services in order to explore a more comprehensive customer experience and more innovative ideas to focus on service improvement [3]; (b) determine priorities for improving the performance of PT X's e-commerce platform services; (c) perfecting and develop work mechanisms to support the improvement of PT X's e-commerce platform service performance. Various integrated approaches have been used in the study methodology, including: Kansei engineering method, service blueprint method, e-service quality method, Kano

model, model linear regression, and Theory of Inventive Problem Solving (TRIZ).

2 LITERATURE REVIEW

2.1 Tables

Service is defined as a sequence of interactions that occur between customers and service providers in order to provide client satisfaction [1]. Because service is an abstract concept, each person's view will vary depending on their personal tastes. An e-commerce platform, as a service, is a platform that anybody can access over the internet and is used by businesspeople to carry out a series of commercial activities and show the products/services being sold [4].

2.2 Kansei Engineering

Kansei is a combination of two words consisting of the words "Kan" and "Sei" derived from Japanese, their combination has the meaning of sensitivity [5]. The Kansei engineering approach aims to translate customer feelings into product/service design specifications [6].

2.3 E-Service Quality

E-service quality is an online service quality assessment method from the functional aspect in providing services effectively and efficiently for its customers.

Assessment of the quality of service functional indicators is carried out by evaluating based on the dimensions of service quality e-service quality as follows [7]:

1. Efficiency

This assessment dimension represents a consumer's or customer's capacity to access services, acquire desired products/services and information with minimal effort.

2. Reliability

This assessment dimension describes the performance of the features and technical aspects provided by a digital platform service.

3. Compensation

This assessment component describes consumer/customer refunds if the service is deemed to be inadequate.

4. Responsiveness

This assessment dimension identifies the level of service providers' willingness to assist consumers/customers and deliver services quickly.

5. Privacy

This assessment dimension describes the level of protection for personal information, the anonymity of its customers, and ensuring the security of customer personal data.

6. Web Design

This assessment dimension describes the level of available selection of colors, feature layouts, selected sizes, and the number of images on a digital platform display.

7. 7. Fulfillment

This assessment dimension describes the level of accuracy in describing products/services on the service site provided and the accuracy of processing an order and delivery time.

2.4 Kano Model

The Kano model is an approach developed by Noriaki Kano in 1984 to categorize product/service quality attributes/indicators. Kano's model considers two aspects of quality attributes, namely the objective aspect which involves the fulfillment of quality and the subjective aspect which involves the customer's perception of satisfaction [8]. Kano model divides quality attributes into five categories, which are as follows:

1. Basic (B)

The basic or must-be quality attributes describe a group of quality attributes that will cause customer dissatisfaction if they are not present in the product/service, but do not contribute significantly to customer satisfaction.

2. One-Dimensional (O)

The basic or must-be quality attributes describe a group of quality attributes that will cause customer dissatisfaction if they are not present in the product/service, but do not contribute significantly to customer satisfaction.

3. Attractive (A)

Attractive quality attribute (A) describes a group of quality attributes that provide a level of consumer/customer satisfaction if fulfilled, but customer satisfaction will not decrease if the quality attribute is not met.

4. Indifferent (I)

Indifferent (I) quality attributes describe a group of quality attributes, the presence or absence of which will not lead to satisfaction or dissatisfaction with customers.

5. Reverse (R)

The reverse quality attribute (R) describes a group of quality attributes, the presence of which causes dissatisfaction and the absence of which leads to customer satisfaction.

2.5 Theory of Inventive Problem Solving (TRIZ)

The TRIZ approach is used to develop innovations in the design of a product or service and address problems with solution guidelines or principles [9]. The TRIZ methodology aids in structuring the process of resolving issues with product/service design by starting with problem definition, then moving on to problem resolution, and concluding with solution evaluation.

3 RESEARCH METHODOLOGY

The study methodology describes a set of research activities carried out from the beginning to the closure of the research stage. The first activity of this study is to identify current problems, define the objectives and limitations of the study's scope, and then undertake a literature review.

The following stage of the study will determine who will be questioned for their thoughts in this investigation. Respondents are owners, tenants, buyers, and property agents who have used e-commerce platform services, as well as PT X's top management. The next study's goal is to collect and analyze respondent data on the service quality attributes of PT X's e-commerce platform. Data collection began with defining the attributes/indicators of respondents' emotional quality based on selected literatures that

have identified Kansei words [10] [11] [12] [13]. A Kansei questionnaire was created based on the literature analysis and provided to 102 respondents (owners, tenants, buyers, and property agents) to evaluate each Kansei word that had been found in the earlier study phase. The Kansei word questionnaire answers served as the foundation for figuring out what kinds of emotional indications of PT X's e-commerce platform services are required by the customers.

Confirmation to PT X has been used to determine the type of improvement to the emotional indicators of PT X's e-commerce platform. To identify quality attributes related to functional aspects, the study was carried out by considering the customer journey of the customer in using the PT X e-commerce platform. To map the customers' journey, the service blueprint method was used [14]. Before proceeding to the next stage, the functional service quality attributes of PT X's e-commerce platform, which had been identified, were tested for their level of reliability and validity. This test is needed to ensure that the respondent's response is a reliable and valid data set for processing and drawing conclusions [15].

The next stage is to collect data to classify categories of functional indicators of PT X's e-commerce platform services. There were 102 respondents who were chosen to fill out the Kano questionnaire. The next stage of the study is to assess the level of fulfillment of the emotional and functional quality attributes/indicators of the PT X e-commerce platform. The fulfillment of the emotional indicator level was completed by calculating the importance and response values of each Kansei word or respondent's emotional indicators. Assessment of the level of fulfillment of functional indicators was carried out by calculating the value of importance, gap, satisfaction score (multiplication between the value of importance and gap), and determining the category of quality attribute groups/functional indicators of PT X's e-commerce platform services based on the Kano model.

This study is then conducted to see what functional and emotional indicators of PT X's e-commerce platform services are the most priority for maintaining service performance according to customers. For this purpose, the linear regression method was used to integrate the level of fulfillment of emotional and functional indicators of PT X's e-commerce platform services, by identifying the relationship between emotional indicators and functional indicators through a linear regression model approach. Linear regression modeling and importance weight calculation solely included functional indicators of service quality attribute group O and A. The goal of this regression modeling is to establish which indicators are the priority for service quality attribute group O and A PT X's O and A e-commerce platform. Linear regression modeling and importance weight calculation do not incorporate the functional indicators of the B quality attribute group, because all B quality indicators/attributes must be met. The study's next stage will determine the service improvement efforts that must be undertaken for PT X's e-commerce platform. The focus of service improvement is on the type of service quality attribute of PT X's e-commerce platform which is classified as a functional indicator with a negative satisfaction score and attribute type B and a functional indicator with a negative satisfaction score and has the highest importance weight. Determination of improvement in e-commerce platform services was conducted using the TRIZ approach. The final stage is designed to perfect and develop several working mechanisms needed to support the improvement of PT X's e-commerce platform service performance.

Table 1: Emotional Indicators

Code	Kansei Terms (Emotional Indicators)
K1	Convenient
K2	Simple
K3	Informative
K4	Innovative
K5	Modern
K6	Attractive
K7	Accurate
K8	Diverse
K9	Flexible
K10	Care
K11	Safe
K12	Practical
K13	Timely
K14	Communicative

4 RESULTS AND DISCUSSION

Quality attributes or emotional indicators are related to service aspects that can arouse customer emotions towards PT X's e-commerce platform services. The Kansei method had been used in this study to: (a) identify emotional indicators, which consist of a collection of Kansei words; (b) then calculate the frequency of occurrence of Kansei words, and (c) choose Kansei words that are in accordance with the service demands of PT X's e-commerce platform. Based on a review of some of the existing literature on Kansei words and confirmed to the top management of PT X, Table 1 below presents 14 types of emotional indicators of PT X's e-commerce platform services needed:

Functional indicators describe the characteristics of the functional capabilities of PT X's e-commerce platform to serve customers. Identification of functional indicators is determined based on the customer journey mapped by the service blueprint method and based on the results of previous research related to digital services [16]. Table 2 below is a description of the functional indicators of PT X's e-commerce platform services, which are considered necessary by the respondents (owners, tenants, buyers, and property agents).

Before being used in further processing, each of the functional indicators of PT X's e-commerce platform services in table 2 above must first be evaluated for their level of validity and reliability. The reliability test is helpful in determining how consistently the scale on the questionnaire generates scores. The validity test is divided into two, namely the convergent validity test which aims to test whether each functional indicator has represented each e-service quality dimension and the discriminant validity test which is useful to see how far the indicators are positively correlated with other dimensions [15]. All indicators had been determined to be reliable and valid based on data processing.

Table 2: Functional Indicators

Code	Functional Indicators
E1	Easy to use
E2	Easy to search product
E3	Displays customer requests in a short time
RL1	Provides updated information
RL2	Accurate search feature
RL3	Provides accurate information
F1	The condition of the real product is in accordance with the listings
F2	Process transactions quickly
F3	Provide complete information for each listing
P1	Ensure transaction safety
P2	Ensure the security of customers' personal information
P3	Ensure customer safety when using the service
RS1	Provide a variety of communication channels
RS2	Respond to customer needs quickly
RS3	Provide appropriate solutions to customer needs and complaints
C1	Provide guarantees if any product is damaged
C2	Provide a guarantee if there is a service that is not as promised
C3	Provide compensation to customers
WD1	Attractive appearance
WD2	Display with a comfortable use of color combinations
WD3	Layout of menus and features are neatly arranged

Table 3: Emotional Mesaurement

Kansei Terms	**Importance Level**	**Response Level**
Convenient	5.35	5.05
Simple	5.09	4.82
Informative	5.50	5.21
Innovative	5.23	4.98
Modern	5.20	5.13
Attractive	5.30	4.98
Accurate	5.51	5.04
Diverse	4.92	4.92
Flexible	5.10	4.96
Care	5.06	4.90
Safe	5.45	5.10
Practical	5.34	5.08
Timely	5.34	5.03
Communicative	5.44	5.25

The calculation of the level of fulfillment of the emotional needs of customers was carried out by calculating the importance and response of each Kansei word or emotional indicator. A questionnaire was distributed to 102 respondents to solicit their views for this purpose. The importance value represented the importance weight of Kansei word, while the response level value described the current performance level of PT X's e-commerce platform in the minds of its customers. Likert scale 1 (lowest) to 6 (highest) were used to assess the importance level and response level as shown by Table 3.

The emotional indicator that reached the second highest response value was "Communicative" (score 5.44). This emotional indicator describes the emotional quality attribute that is considered necessary compared to other emotional indicators beside the "accurate" emotional quality attribute. Communicative here is defined as a type of service feature that is able to convey information well and easy to understand. This was proven by the performance of e-commerce platform services that have provided a good response level score (score 5.25). However, efforts to continue to improve the service performance of the "communicative" aspect of the indicator

Table 4: Functional Measurements

Code	Importance Level	Gap Level	Satisfaction Score	Kano Category
E1	5.41	-0.29	-1.58	I
E2	5.45	-0.29	-1.59	I
E3	5.23	-0.19	-0.98	I
RL1	5.42	-0.34	-1.86	I
RL2	5.40	-0.44	-2.36	O
RL3	5.48	-0.43	-2.34	O
F1	5.39	-0.38	-2.02	O
F2	5.26	-0.38	-1.97	I
F3	5.39	-0.44	-2.36	I
P1	5.47	-0.48	-2.62	O
P2	5.49	-0.49	-2.69	O
P3	5.45	-0.41	-2.21	O
RS1	5.23	-0.22	-1.14	O
RS2	5.38	-0.46	-2.46	B
RS3	5.33	-0.30	-1.61	O
C1	5.25	-0.36	-1.91	O
C2	5.25	-0.41	-2.13	O
C3	5.17	-0.38	-1.94	O
WD1	5.28	-0.20	-1.05	O
WD2	5.31	-0.21	-1.11	I
WD3	5.32	-0.33	-1.77	I

will continue to conduct. Based on the discussions with management of PT X, the "communicative" indicator features that will be enhanced are: (a) improvement of advertising content features; (b) improvement of font and color characters to make it easier for customers to surf information on PT X's e-commerce platform; (c) training for employees of the Customer Service work unit in explaining the product knowledge offered; (d) improvements to the FAQ-Frequently Asked Questions feature on the PT X e-commerce platform.

Assessment of the level of fulfillment of customer functional needs was completed by measuring the value of importance, gap, satisfaction score, and determining the attribute type category of each functional indicator. There were 102 respondents (owners, buyers, tenants, and property agents) had been asked for their thoughts to determine the level of fulfillment of customer functional needs for the performance of PT X's e-commerce platform services. This assessment was performed using the Kano method and the result is shown in Table 4.

Based on the results of the Kano method processing, there was 1 type of indicator B (basic), 12 types of indicator O (one-dimensional), and 8 types of indicator I (indifferent) for PT X's e-commerce platform services. Based on table 4, it was found that all functional indicators functional services in categories B and O showed a negative gap value. This condition means that the achievement of the service performance level of all functional indicators for categories B (basic) and O (one-dimensional) cannot meet customer expectations, and they require service improvement. The gap value also affected the satisfaction score for each functional indicator. Functional indicators that will be further processed in the next stage is functional indicators with a negative satisfaction score. Satisfaction score represents the level of customer satisfaction with the functional indicators of services provided by the PT X's e-commerce platform. A negative satisfaction score indicates that customers are not satisfied with the functional indicators provided by the PT X's e-commerce platform.

According to the results of categorizing functional indicators using Kano's model, functional indicators are classified into three sorts of attributes: one-dimensional, basic, and indifferent. Functional indicators that are the target of further data processing enhancement, especially only functional indicators classified as one-dimensional (O), basic (B), and attractive (A) attribute categories. This is due to the fact that attribute types O and A have the greatest influence on customer satisfaction [3], while attribute type B is something that must exist in the service. If the three types of indicators can fulfill consumer expectations, it is expected that they will deliver high customer satisfaction and, as a result, have an impact on the success of PT X's e-commerce platform services.

The linear regression model was used to determine which service indicators (functional and emotional) from PT X's e-commerce platform must be maintained. The linear regression model's function is to reveal which integration types of PT X's e-commerce platform service indicators (both functional and emotional) are relevant. Linear regression modeling and importance weight calculation only included functional indicators of attribute type O and A. Linear regression modeling and importance weight calculation were not performed for functional indicators of attribute type B. This was due to the fact that all indicators of attribute B must be enhanced. To produce an accurate linear regression model, it is necessary to determine which emotional indicators are related and indeed significantly influenced by functional indicators by using an affinity

Table 5: Linear Regression Model

Kansei Words	Linear Regression Model
Convenient	Convenient = 3.282 + 0.049RS1 + 0.337RS3
Informative	Informative = 2.681 + 0.364RL3 + 0.033F1 + 0.124RS3
Innovative	Innovative = 2.159 + 0.324RS1 + 0.259WD1
Attractive	Attractive = 2.655 + 0.499WD1
Accurate	Accurate = 1.624 + 0.774RL2 + 0.151RS3
Flexible	Flexible = 3.267 + 0.161RS3 + 0.192C2
Care	Care = 1.950 + 0.035C1 + 0.551C2 + 0.016C3
Safe	Safe = 0.783 + 0.117F1 + 0.176P1 + 0.550P3 + 0.142RS3 + 0.047C2 + 0.064C3
Communicative	Communicative = 1.953 + 0.312RS1 + 0.355RS3

diagram [3]. The following is the linear regression formula used, and Table 5 shows the formula for each Kansei word.

$$y = a + b_1x_1 + +b_2x_2 + \ldots + +b_nx_n \tag{1}$$

y : Emotional indicators importance level
x_n : Functional indicators importance level
b_n : Constant value

The outcomes of the linear regression model in Table 5 demonstrate a positive correlation between the importance of several functional indicators and an emotional indicator of PT X's e-commerce platform services. The higher the importance of an emotional indicator of platform services for e-commerce PT X, the more significant the importance of numerous functional indications of a service.

The next stage is to determine the indicators that become the priority of service improvement by assessing the importance weight for each functional indicator. Here is the formula for calculating the importance weight of e-commerce platform services:

$$\text{Importance weight} = |\text{Satisfaction score}| \times (\text{Kano weight}) \times \text{Emotional indicators response level} \tag{2}$$

Based on Table 6, the functional indicator with the highest importance weight and becomes a priority for service improvement, namely the RS3 indicator "Provide appropriate solutions to customer needs and complaints." (score 98.56). In addition, after discussing with the management of PT X, the functional indicator of C2 (one-dimensional category) was called as "Provide a guarantee if there is a service that is not as promised" and F1 (one-dimensional category) was named "The condition of the "real product is in accordance with the listings" was chosen to be corrected, because both functional indicators C2 and F1 have high importance weights rated by customers (scores of 63.73 and 44.20, respectively).

Based on tables 5 and 6, the functional indicators of RS2, RS 3, C2 and F1 have negative satisfaction scores and are significantly related to other emotional indicators (accurate, communicative, informative, convenient, and flexible).

The RS3 indicator is an important indicator to be fulfilled by PT X's e-commerce platform services in order to help customers appropriately. If the RS 3 indicator cannot be met, it is predicted that customers will be disappointed and will not get a solution for complaints or problems encountered when using PT X's e-commerce platform services. The functional indicator with the second highest importance weight is the C2 indicator "Provide a guarantee if there is a service that is not as promised". The C2 indicator is something that is important to be fulfilled by a service because if the indicator does not keep its promise at the beginning, then PT X needs to provide financial compensation for the customer/buyer so that the customer is not disappointed. The functional indicator with the third highest importance weight is the F1 functional indicator "The condition of the real product is in accordance with the listings". F1 functional indicators are also something that is considered important. The F1 functional indicator describes the real condition of the property being offered. The mismatch of property conditions between what is offered and the real condition risks will cause customer disappointment.

In terms of the basic functional indicator "Respond to customer needs quickly (RS2)" and the O-one-dimension functional indicator "Provide appropriate solutions to customer needs and complaints (RS3)," the customer service work unit that serves and responds to customer complaints is currently deemed unable to meet customer needs while also providing appropriate and timely solutions. Based on conversations with PT X management, it was determined that the abilities possessed by employees of the customer service (CS) work unit were deemed insufficient. This is due to the fact that PT X has recently recruited on a big scale to fulfill the needs of the employees of this CS work unit, hence the majority of the CS work unit's employees have a tenure of less than one year. In fact, tenure has a significant effect on the competencies possessed by employees [19]. The longer an employee's term of office, the more qualified the employee's degree of competency. The negative results on the satisfaction score in table 4 support the assumption that the CS work unit workers' service performance is deemed unsatisfactory. Currently, with 30 personnel in PT X's CS work unit, there were indicators that employee competence and performance continue to vary and were regarded insufficient to support the performance of PT X's intended e-commerce platform services. As a result, it is critical for PT X to concentrate and prioritize efforts to develop the two functional indicators mentioned above (the RS2 and RS3 indicator/attribute groupings).

The TRIZ method was used to prioritize the repair of PT X's e-commerce platform services. The first stage of improvement was to define the problem. During the problem definition step, problems that occurred in services relevant to the RS2 and RS3 service indicators were identified. The identification of difficulties was useful as a roadmap for developing a strategy for improving PT X's

Table 6: Importance Weight Measurement

Code	Satisfaction Score	Kano Category		Response Level		Importance Weight
RL2	2.36	O	2	K7	5.04	23.79
RL3	2.34	O	2	K3	5.21	24.38
F1	2.02	O	2	K3	5.21	44.20
				K11	5.1	
P1	2.62	O	2	K11	5.1	26.72
P3	2.21	O	2	K11	5.1	22.54
RS1	1.14	O	2	K1	5.05	34.84
				K4	4.98	
				K14	5.25	
RS3	**1.61**	**O**	**2**	**K1**	**5.05**	**98.56**
				K3	**5.21**	
				K7	**5.04**	
				K9	**4.96**	
				K11	**5.1**	
				K14	**5.25**	
C1	1.91	O	2	K10	4.9	18.72
C2	2.13	O	2	K9	4.96	63.73
				K10	4.9	
				K11	5.1	
C3	5.17	O	2	K10	4.9	38.80
				K11	5.1	
WD1	5.28	O	2	K4	4.98	20.92

e-commerce platform offerings. The next step was to conduct problem resolution. The identification of system parameters that may be at odds with one another is the foundation for problem solving [20]. Based on the TRIZ solution principle, which was more than 3, the choice of the solution principle was made. The contradiction matrix's frequency of occurrence was greater than 3. The TRIZ solution idea was used to implement a number of options for enhancing PT X's e-commerce platform services. Then, for validation, different alternative enhancements were verified with PT X. An overview of the proposed improvements to PT X's e-commerce platform services is provided below:

- Conducting intensive training programs for employees of customer service work units.
- Perfecting SOP (standard operating procedure), developing work instructions, and improving SLA (service level agreement) in appropriate discipline in the process of responding and providing solutions to customer complaints in order to reduce the possibility of errors by employees of the customer service work unit.

The existing training conditions at PT X are considered to be focused only on the needs of the employees and not on a routine basis. In addition, PT X has never compiled the types of training modules that are in accordance with the demands of the work of the CS work unit. Furthermore, the training materials provided so far have only been delivered verbally by instructors or senior employees at PT X without being documented in any form. As a result, when CS work unit employees want to re-access, there is difficulty in accessing information on training material documents and they need to ask other employees again.

Regarding the proposal to conduct a training program, this study has developed various relevant training modules by containing information per type of training module as follows: name of training; the main objectives of the training are related to the types of competencies and skills that will be realized after the training; duration of training time (in hours); references used for training; training media (online or offline). For the purposes of the training program, the employee training modules needed to properly manage PT X's e-commerce platform include: the ability to properly use the features of the e-commerce platform; tips for responding to customer answers appropriately; the ability to communicate customer complaints to other departments; and many more. The produced training module is then proposed to be routinely distributed to employees of the CS work unit. Based on input from PT X management, training is implemented at least twice a week on topics relevant and needed by employees of the CS work unit. The goal of twice-weekly training for employees of PT X's CS work unit is to keep employees up to date on the latest knowledge and to continue to develop employees' abilities in responding to client demands and complaints. SOPs describe specific procedures to describe the series of activities required to complete official duties for CS unit employees by taking into account industry regulations, laws or standards for the CS function. In addition, for CS activities in the SOP which are considered to need to be explained in much more detail, work instructions (IK) are feasible to be developed. This study has also developed some relevant IK. IK explains the series of jobs that CS employees need to do in completing an activity. The SOP and IK that have been prepared are then proposed to be trained regularly. Furthermore, monitoring efforts on the implementation of the SOP

and IK are proposed to be carried out regularly to ensure changes in attitudes and work behavior of CS work unit employees after training.

SLA describes the level of service performance of CS work unit employees that is intended to be accomplished by establishing and applying specified metrics to assess CS work unit employees' level of service performance [21]. The suggested SLA design also examines the type of penalty that will be imposed on CS work unit personnel if the agreed-upon service performance level is not met. The completion of the SLA contents contains information on the degree of performance of certain services that must be realized; service performance targets; and the sort of penalty that will be accepted if it is not accomplished.

The main objective of developing and implementing SOP, IK, and SLA is to ensure that the attitudes and work behaviors of CS work unit employees have a good and consistent level of performance in supporting a systematic, orderly, organized, and accountable work system. So far, SOP, IK, and SLA have been partially provided by PT X, but are still considered not complete enough and are obeyed in an orderly manner by all employees of the CS work unit. This is due to the absence of a performance control that functions to directly ensure the implementation of SOP, IK, and SLA has been carried out correctly by CS employees.

Following extensive discussions with PT X, it was determined that supervision of the implementation of SOP, IK, and SLA was required. As a result, the supervisor and manager of the CS work unit have been asked to guarantee that 30 employees are correctly escorting the SOP, IK, and SLA implementation. This is significant since the company's control over its employees is significantly and positively related to employee performance. [22]. To support this supervision, routine performance reviews and evaluations are proposed to be carried out to ensure the implementation of SOP, IK, and SLA has been carried out properly in the CS work unit. In implementing the performance review, it is proposed to hold regular sharing sessions between employees and supervisors as well as CS work unit managers to discuss the results of performance reviews and evaluations. This regular sharing session also aims to convey criticism, suggestions and consultations, and follow up on improvements to the attitudes and work behavior of CS work unit employees in managing PT X's e-commerce platform.

5 CONCLUSION

The purpose of this study is to improve the performance of PT X's e-commerce platform services. There were 14 types of emotional indicators developed based on the Kansei word literature. However, there were only 9 service indicators that were considered further in this study, namely: convenient, informative, innovative, attractive, accurate, flexible, care, safe, and communicative. The 3 types of emotional quality indicators that are considered the most important in managing PT X's e-commerce platform are accurate, communicative, and informative. The results of the study also noted that the customer response level on 9 emotional indicators was considered to need to be more improved.

There were 21 different types of functional indicators used to describe the quality of PT X's e-commerce platform management. All basic and one-dimensional functional indicators had a negative satisfaction score, indicating that e-commerce platform service performance is still deemed inadequate. Given the restricted resources and perspectives of PT X's top management, the study's priority of service enhancement results in one type of basic indicator (RS2) and three types of one-dimensional functional indicators (RS3, C2, and F1).

Furthermore, the proposed improvement of the working mechanism needed to support the performance of PT X's e-commerce platform services is as follows:

- developing training modules for CS work unit employees;
- conducting regular training twice a week for employees of the CS work unit;
- perfecting and proposing the consistent application of SOPs and work instructions needed to complete the implementation of the duties of employees of the CS work unit;
- improving the SLA (service level agreement) for employees of the CS work unit;
- propose a supervisory mechanism for the implementation of SOPs, work instructions, and SLAs to shape the professional attitudes and work behavior of CS work unit employees required by PT X;
- designing and proposing the implementation of periodic performance reviews and evaluations;
- propose sharing activities between employees and supervisors as well as CS work unit manager to make improvements in managing PT X's e-commerce platform.

The required further study suggestions are:

- taking into account the latest digital technologies such as Augmented Virtual and Virtual Reality or on the Metaverse platform for features of e-commerce platform;
- assessing the competency needs of CS work unit employees as the basis for developing a competency-based training module for positions;
- developing a maturity level assessment model for e-commerce platform management.

REFERENCES

[1] A. Parasuraman, L. L. Berry, dan V. A. Zeithaml, "More on improving service quality measurement," J. Retail. 69.1, vol. 69, pp. 140–147, 1993.
[2] J. Wu, Y. Wang, R. Zhang, dan J. Cai, "An approach to discovering product/service improvement priorities: Using dynamic importance-performance analysis," Sustainability, vol. 10, no. 10, 2018, doi: 10.3390/su10103564.
[3] M. Hartono, A. Santoso, Di. N. Prayogo, dan Ivon, "The extended framework of kansei engineering, kano and TRIZ applied to logistics services," IEEE Int. Conf. Ind. Eng. Eng. Manag., vol. 2017-Decem, pp. 1159–1163, Feb 2017, doi: 10.1109/IEEM.2017.8290074.
[4] V. Alfonso, C. Boar, J. Frost, L. Gambacorta, dan J. Liu, "E-commerce in the pandemic and beyond," BIS Bulletin 36.9, 2020.
[5] S. Schütte, "Designing feelings into products: Integrating kansei engineering methodology in product development," Linkopings Universitet. Sweden, 2002.
[6] D. Nizaora, D. Cahyadi, E. F. Soeprapto, R. Ahmad, S. Jepriani, dan R. S. P. Rinda, "Safety Hijab Design for Engineering Practical Usage Among Students by Kansei Engineering Method," 2021, doi: 10.2991/assehr.k.210424.031.
[7] A. Parasuraman, V. A. Zeithaml, dan L. L. Berry, "A Conceptual Model of Service Quality and Its Implications for Future Research," J. Mark., vol. 49, no. 4, pp. 41–50, Sep 1985, doi: 10.1177/002224298504900403.
[8] Y. Yang, Y. Guo, M. Ma, dan J. Hu, "Analysis of SMC Marketing System and Research of Customer Loyalty Identification based on HMM," Adv. Intell. Syst. Comput., vol. 1001, pp. 794–812, Agu 2019, doi: 10.1007/978-3-030-21248-3_60.
[9] Genrich Altshuller, 40 Principles: TRIZ Keys to Innovation. Worcester: Technical Innovation Center, 2002.
[10] Y. H. Hsiao, M. C. Chen, dan W. C. Liao, "Logistics service design for cross-border E-commerce using Kansei engineering with text-mining-based online

content analysis," Telemat. Informatics, vol. 34, no. 4, pp. 284–302, Jul 2017, doi: 10.1016/J.TELE.2016.08.002.

[11] A. N. Habyba, T. Djatna, dan E. Anggraeni, "A System Analysis and Design for SMEs Product Presentation on E-commerce Website based on Kansei Engineering (Case Study: SMEs Products of Ponorogo Regency)," Adv. Intell. Syst. Comput., vol. 739, pp. 20–29, 2018, doi: 10.1007/978-981-10-8612-0_3.

[12] S. A. H. Bidin dan A. M. Lokman, "Enriching the Comfortability Emotion on Website Interface Design Using Kansei Engineering Approach," Adv. Intell. Syst. Comput., vol. 739, pp. 792–800, 2018, doi: 10.1007/978-981-10-8612-0_82.

[13] A. Lokman, N. Noor, dan M. Nagamachi, "Kansei database system for emotional interface design of e-commerce website," 2008.

[14] A. R. Putriya, P. Hermawan, S. Novani, dan U. S. Putro, "Peer-to-Peer Accomodation Service Process: A Framework of Service Blueprint," in Proceedings of the 12th International Conference on Business and Management Research (ICBMR 2018), Mar 2019, pp. 211–217, doi: 10.2991/ICBMR-18.2019.35.

[15] Malhotra, Nunan, dan Birks, Marketing Research: An applied approach, 5th ed. New Jersey: Pearson, 2017.

[16] R. D. Kusumadewi, S. Wulandari, dan R. Aurachman, "Designing Magma Apparel E-Commerce Service Needs using Refined Kano and E-Servqual Methods," in eProceedings of Engineering, Agu 2020, vol. 7, no. 2, [Online]. Available at: https://openlibrarypublications.telkomuniversity.ac.id/index.php/engineering/article/view/13162/12800.

[17] M. N. Hajli, J. Sims, M. Featherman, dan P. E. D. Love, "Credibility of information in online communities," J. Strateg. Mark., vol. 23, no. 3, pp. 238–253, Apr 2014, doi: 10.1080/0965254X.2014.920904.

[18] A. Ganapathy, "View of Virtual Reality and Augmented Reality Driven Real Estate World to Buy Properties," Asian J. Humanit. Art Lit., vol. 3(2), pp. 137–146, 2016, doi: 10.18034/ajhal.v3i2.567.

[19] N. Tiraieyari dan J. Uli, "Moderating effects of employee gender and organizational tenure in competency-performance relationships," African J. Bus. Manag., vol. 5, no. 33, pp. 12898–12903, 2011, doi: 10.5897/AJBM11.2399.

[20] F. Li, "A Study on Innovative Design of Rotary Pile Foundation Drilling Machine Based on TRIZ Theory," Mech. Mach. Sci., vol. 77, pp. 302–309, Agu 2019, doi: 10.1007/978-981-32-9941-2_26.

[21] I. M. Gerard Blokdijk, The Service Level Agreement SLA Guide - SLA book, Templates for Service Level Management and Service Level Agreement Forms. Fast and Easy Way to Write your SLA. Emereo Publishing, 2008.

[22] B. van der Kolk, P. M. G. van Veen-Dirks, dan H. J. ter Bogt, "The Impact of Management Control on Employee Motivation and Performance in the Public Sector," Eur. Account. Rev., vol. 28, no. 5, pp. 901–928, Okt 2019, doi: 10.1080/09638180.2018.1553728.A

Optimization of Production Planning Using Goal Programming and Inventory Control Based on Demand Forecasting Using Neural Networks on CV Bahyu Perkasa

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ABSTRACT

CV Bahyu Perkasa is a company engaged in the concrete construction industry. One of the products produced is paving block. The number of fluctuating demands makes the company decide to stockpile products and procure raw materials regularly to meet consumer demand. This was Born in over-production and overstock. Therefore, a consumer demand forecasting method is needed so that it can minimize production costs and maximize profits. In addition, inventory control methods are needed to reduce storage costs and ordering costs for raw materials. The method used for demand forecasting is an artificial neural network with an MSE error accuracy rate of 0.017769. Forecasting results are used to optimize production planning using goal programming and inventory control planning using MRP. The results of the goal programming optimization model with priority determination produce an optimal solution in fulfilling consumer demand and minimizing production costs of Rp. 99,205,774.00.

CCS CONCEPTS

• **Applied Computing**; • **Operations Research**; • **Industry and Manufacturing**;

KEYWORDS

Optimization, Production Planning, Forecasting, Artificial Neural Network, Goal Programming

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1 INTRODUCTION

CV Bahyu Perkasa is a company engaged in concrete construction. The production process applied by the company uses two methods: make to stock and make to order. Products made with make-to-stock are products with a high enough demand, while products made with make-to-order are products with unique specifications from consumers, and the number of requests is low [1].

The paving block is one of CV Bahyu Perkasa's products which is produced with a make-to-stock system because the number of requests is relatively high. However, the pandemic conditions in 2020 resulted in a drastic decline in demand. Table 1 shows sales number of Paving blocks TP6 250.

Table 1: Sales number of Paving Block TP6 250

Month	Years		
	2019	2020	2021
Jan	2324	2853	1795
Feb	941	1686	195
Mar	1586	1729	1442
Apr	985	90	1075
Mei	1451	570	1015
Jun	794	1587	0
Jul	1043	285	664
Agu	1896	1213	1551
Sep	1173	1107	1238
Oct	780	0	1560
Nov	901	1086	1015
Des	2252	1347	1852
Total	16126	13553	13402

The pandemic condition has occurred in Indonesia since March 2020. From Table 1, it can be seen that there has been decreased number of requests for paving blocks from 2019 to 2021. Even though the company is aware of the declining demand, the company cannot stop production activities because of the need to pay workers. Workers at CV Bahyu Perkasa are paid according to the products produced, so if the company does not carry out the production process, the workers will not get wages. Table 2 shows CV Bahyu Perkasa's Production and Sales Data in 2020

Table 2 shows that in the 8th, 11th, and 12th months, the total production of paving blocks is 0. This is because there were other

Table 2: Production and Sales Data Comparison 2020

Month	Production of Paving Block TP6 250 (mtr/pcs)	Sales of Paving Block TP6 250 (mtr/pcs)	Inventory
1	3281	2853	428
2	3790	1686	2532
3	3465	1729	4268
4	1096	90	5274
5	519	570	5223
6	1267	1587	4903
7	1230	285	5848
8	0	1213	4635
9	1351	1107	4879
10	941	0	5820
11	0	1086	4734
12	0	1347	3387
Total	16940	13553	

projects being worked on by CV Bayu Perkasa. CV Bayu Perkasa's problem is that the company does not yet have a strategic methodology to determine the number of products that need to be produced in the future, especially for products produced with a make-to-stock system. This resulted in product accumulation, especially during the pandemic, reaching 3387 meter/pcs.

Therefore, it is necessary to forecast the number of requests using the Artificial Neural Network (ANN) method. Modeling with mathematical methods such as ANN can optimize resources because their needs have been predicted previously [2]. ANN is a method that can use to make predictions with non-linear and complex data [3]. ANN has proven to be an efficient classification and predictive accuracy without prior system knowledge [4]. The ANN method can also be used for relatively small data conditions [5]. ANN predicts by exploring the relationship between variables to understand very complex structures, both linear and non-linear data, in a relatively short time [6]. The ANN method was used in this study because of the fluctuating number of requests for CV Bahyu Perkasa and relatively few data. The artificial network method can learn from the data and is non-linear to identify the model's structure, and is effective in connecting input-output simulations with fluctuating and relatively little data [7]. According to Rosmala Sari and A. Sudiarso, ANN can predict aggregate product groups more accurately than traditional demand forecasting. Then aggregate planning is carried out from the forecasting results to produce stock arrangements much better than the initial conditions [8].

The results of demand forecasting using ANN become data for optimizing production planning using the goal programming method. Goal programming (GP) is a method that can solve linear programming problems with more than one goal [9]. GP has been widely used as a multi-objective decision-making tool in past decades: in logistics, environmental studies, manufacturing, and economics [10]. GP can use several weighting criteria [11]. Several types of GP are distinguished in the weighting of the objective function, including Weighted Goal Programming (WGP), Lexicographic Goal Programming (LGP), and Minmax Goal Programming (Minmax GP) [12]. One of the uses of Linear Goal Programming has been to find solutions in the petroleum industry that have many goals [13]. GP can provide unwanted deviation variables and combine several objective functions [14]. Programming Objectives are used in the research at CV Bahyu Perkasa because they have four functions: meeting demand, utilizing regular working hours, dealing with working hours, and production costs. Each objective function has different boundaries and priority scales.

2 RESEARCH METHODOLOGY

The research process begins with a literature study and field study to identify problems in the system. After finding the problem, then determine the objective research and determine the method of solving the problem. The method used in this study consists of 2 stages, namely: the demand forecasting process using the Artificial Neural Network (ANN) method and optimizing production planning using goal programming. Figure 1 explain the methodology of the research carried out.

3 DATA COLLECTION AND ANALYSIS

3.1 Demand Forecasting with Artificial Neural Network (ANN)

Forecasting is one of the methods commonly used to help organizations with capacity planning, goal setting, and anomaly detection [15]. Demand forecasting makes it easier for companies to determine the amount of production that needs to be done in the future and helps determine the number of raw materials that need to be prepared in the production process [16] [17]. The method used in forecasting demand in this paper is artificial neural network (ANN). This is due to the fluctuating characteristics of the company's demand. The predicted product will only focus on Paving Block TP6 250 products as the product that has the highest demand and is a top priority for the company. Figure 2 shows the fluctuating number of requests for Paving Block TP6 250 in 2019 to 2021.

Plotting the demand listed in Figure 2, it is known that the data pattern is obtained randomly and does not form a certain trend,

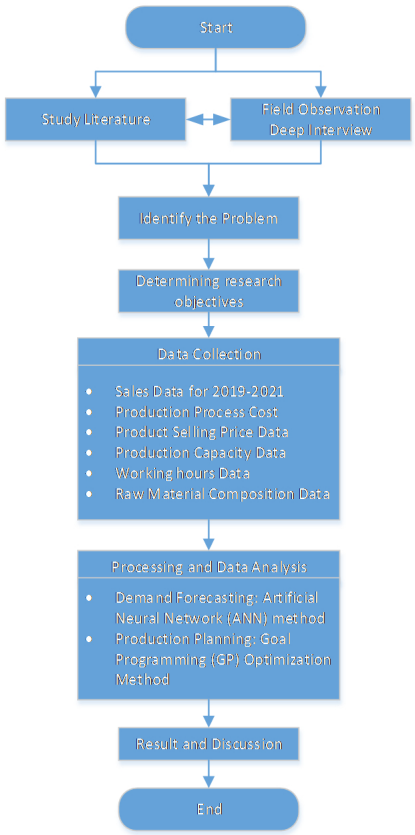

Figure 1: Research Methodology

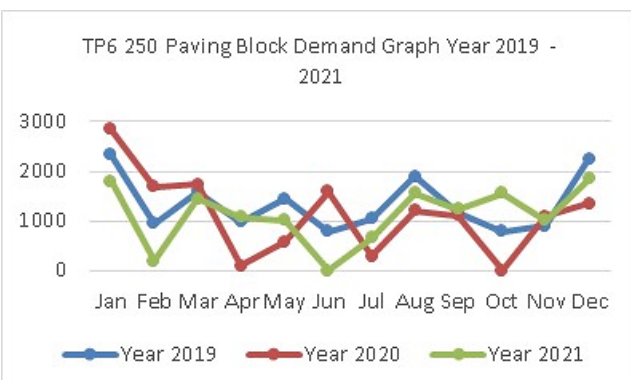

Figure 2: number of requests for Paving Block TP6 250 in 2019 to 2021

such as: seasonality, or others. Artificial neural networks that are deep learning can provide predictive output from stationary data and the linearity is not met [18]. Determination of the best network architecture is obtained from the training process and data testing. The data is divided into two, namely training and testing data. Preprocessing and data normalization is the first step before conducting the data training and testing process. Normalization functions to use the sigmoid activation function (binary), where the data must be transformed first because the output range of the sigmoid activation function is [0,1] [19]. Table 3 is the normalized TP6 250 Paving Block demand data.

The artificial neural network architecture used in this study is a multi-layer network model with backpropagation and predetermined parameters, namely Levenberg Marquardt (trainlm), with epoch 1000 with network model 12-32-10-1 and activation function [logsig, logsig, purelin]. The target MSE value is 0.00001. The data in Table 3 is divided into 3 groups, training data, testing data, and output data. The input for training data is data number 1-12 (demand data for 2019), and the results will be compared with data number 13-24 (data demand for 2020). The training data input is data number 13-24, and the results will be compared with data number 25-36 (demand data for 2021). While the output data input is data numbers 25-36, and the result is a demand forecast for 2022.

The results of the training process with the 12-32-10-1 network are shown in Figure 3, which produces an MSE value of 2.9114e-. The output of ANN at the training stage produces a good level of prediction accuracy. The training process aims to make the artificial neural network reach convergence and understand the network pattern from the parameters and algorithms that have been determined.

The testing process requires a weight calculation, namely the calculation of the weight of the input to the layer, the calculation of the weight of the layer to the output, the calculation of the bias weight to the layer, and the calculation of the bias weight to the output layer. The testing process by calculating weights and biases to get test results with an MSE of 0.017769 which is quite accurate.

The results of the ANN output in the testing process with initial weight and bias calculations, also produce demand forecasting for the period January 2022 to December 2022. The results of the demand forecasting that have been denormalized can be seen in Table 4.

Table 4 is the result of prediction demand forecasting from the ANN method. Table 4 is the result of prediction demand forecasting from the ANN method. These results become input for the production planning process. The limitation of demand data for other types of paving is overcome by using data on the proportion of requests for each paving from 2020-2021. The various types and quantities of requests and their proportions are shown in Table 5.

3.2 Production Planning with Goal Programming (GP)

The goal programming model is used for complex problems that can solve more than 1 objective function with optimal solution results that the linear programming model cannot solve [20]. This study uses four objective functions in order of priority as follows, namely: fulfillment of demand, utilization of regular working hours, minimizing the number of overtime hours, and maximizing profits. So that the objective function is formed as follows:

$$Min\ Z = \sum_{i=1}^{5} \left(d_i^- + d_i^+\right) + d_6^+ + d_7^+ + d_8^+ + \sum_{i=9}^{12} d_i^+ \qquad (1)$$

Determination of the decision variables is needed to determine the decision variables clearly for the unknown variables to proceed

Table 3: Demand Normalization Data

Number of data	Normalization data	Number of data	Normalization data	Number of data	Normalization data
1	0.751665	13	0.9	25	0.60333
2	0.363863	14	0.572766	26	0.154679
3	0.544725	15	0.584823	27	0.504346
4	0.3762	16	0.125237	28	0.401437
5	0.50687	17	0.259832	29	0.384613
6	0.322643	18	0.545005	30	0.1
7	0.392464	19	0.179916	31	0.28619
8	0.631651	20	0.440133	32	0.534911
9	0.428917	21	0.41041	33	0.447143
10	0.318717	22	0.1	34	0.537434
11	0.352646	23	0.404522	35	0.384613
12	0.731476	24	0.477708	36	0.619313

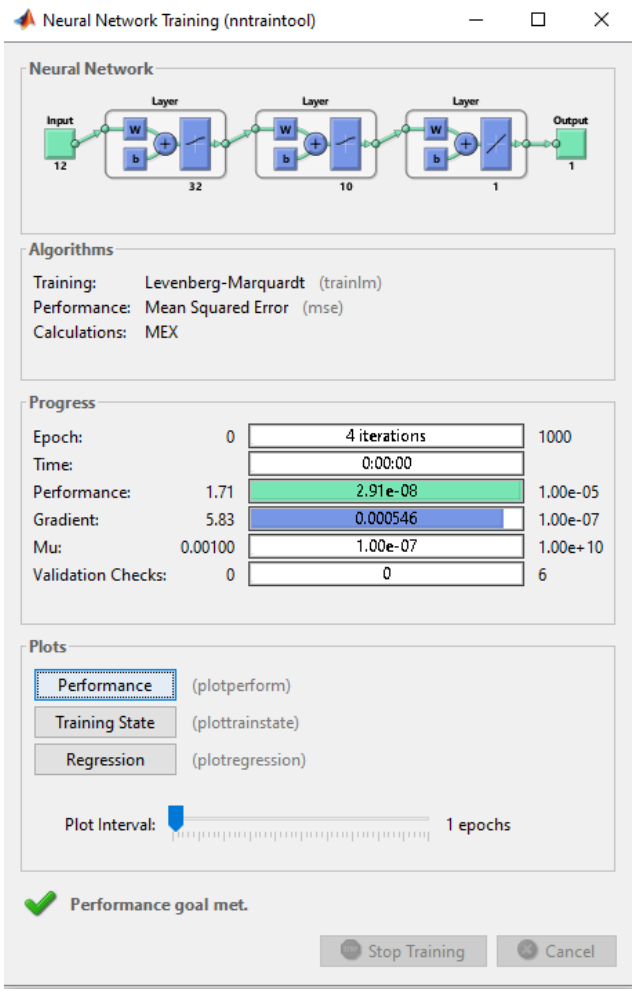

Figure 3: Network Training Results 12-32-10-1

Table 4: Results of demand forecasting with the ANN method

Prediction Results Using ANN Method 12-32-10-1		
Period	Result Prediction	Denormalization Prediction
Jan-22	0.4769024	1392
Feb-22	0.272643162	686
Mar-22	0.424894043	1212
Apr-22	0.458526551	1328
May-22	0.344087869	933
Jun-22	0.464351997	1348
Jul-22	0.28976909	745
Aug-22	0.434675981	1246
Sep-22	0.214041042	484
Oct-22	0.408974241	1157
Nov-22	0.564908187	1696
Dec-22	0.292814266	756

to the modeling stage [21]. The following decision variables are used in the CV Bahyu Perkasa goal programming optimization model below:

X1 = Product decision variable for paving block TP6 250
X2 = Product decision variable for paving TP6 350
X3 = Product decision variable for paving TP8 250
X4 = Product decision variable for paving TP8 350
X5 = Product decision variable for paving Hexagon
d_1^-= Variable deviation under paving block request TP6 250
d_1^+= Variable deviation upper paving block request TP6 250
d_2^-= Variable deviation under paving block request TP6 350
d_2^+= Variable deviation upper paving block request TP6 350
d_3^-= Variable deviation under paving block request TP8 250
d_3^+= Variable deviation upper paving block request TP8 250
d_4^-= Variable deviation under paving block request TP8 350
d_4^+= Variable deviation upper paving block request TP8 350
d_5^-= Variable deviation under paving block request exagon
d_5^+= Variable deviation upper paving block request hexagon
d_6^-= Variable deviation under regular working hours
d_6^+= Variable deviation upper regular working hours
d_7^-= Variable deviation under overtime hours

Table 5: Demand Proportion for each type of paving block

The number of Paving Request 2020-2021				
Paving Block TP6 250 (X1) 26955	Paving Block TP6 350 (X2) 2654	Paving Block TP8 250 (X3) 4491	Paving Block TP8 350 (X4) 110	Paving Block Exagon (X5) 872
Demand Proportion				
76.83%	7.57%	12.80%	0.31%	2.49%

$d_7{}^+$= Variable deviation upper overtime hours
$d_8{}^-$= Variable deviation below production cost
$d_8{}^+$= Variable deviation above production cost
$d_9{}^-$= Variable deviation under the use of cement raw materials
$d_9{}^+$= Variable deviation upper the use of cement raw materials
$d_{10}{}^-$= Variable deviation under the use of sand raw materials
$d_{10}{}^+$= Variable deviation upper the use of sand raw materials
$d_{11}{}^-$= Variable deviation under the use of screening stone raw materials
$d_{11}{}^+$= Variable deviation upper the use of screening stone raw materials
$d_{12}{}^-$= Variable deviation under the use of rock ash raw material
$d_{12}{}^+$= Variable deviation upper the use of rock ash raw material
The fulfillment of each objective function has constraints built into a system's boundaries. The constraint function and each objective function are described as follows.

3.2.1 Request constraint function. The demand constraint function is created by adjusting the results of the demand forecast every month.

Constraint Function:

$$x_1 + d_1{}^- - d_1{}^+ = a_{1k} \tag{2}$$

$$x_2 + d_2{}^- - d_2{}^+ = a_{2k} \tag{3}$$

$$x_3 + d_3{}^- - d_3{}^+ = a_{3k} \tag{4}$$

$$x_4 + d_4{}^- - d_4{}^+ = a_{4k} \tag{5}$$

$$x_5 + d_5{}^- - d_5{}^+ = a_{5k} \tag{6}$$

Objective Function:

$$Min\ Z = \sum_{i=1}^{5} \left(d_i{}^- + d_i{}^+\right) \tag{7}$$

When:
$d_i{}^-$= Variable deviation under the paving block type request
$d_i{}^+$= Variable deviation above the paving block type request
a_{ik}= Number of requests for the type of paving block
i= Types of paving block products (i = 1, 2, . . .5)

3.2.2 Regular working hours constraint function. The availability of working hours as a constraint function is used to see the relationship between production time and the number of products produced. The formulation used to formulate this constraint function is as follows:

$$\sum_{i=1}^{5} A_i X_i \leq \sum_{j=1}^{12} JK_j \tag{8}$$

When:
A = Time required to produce 1 m/pcs paving block
X = Decision variables for the type of paving block product
JK = Number of available regular working hours
i = Types of paving block products (i = 1, 2, . . .5)
j = Month (1, 2. . .. 12)

3.2.3 Overtime Constraint Function. The speed for producing all types of products, 1 m/pcs paving block, is the same, with 4 minutes of processing time required. If the demand is high, the company holds an overtime policy with maximum overtime of 20 working days in 1 month with a working time of 5 hours. Therefore, the maximum overtime allowed by the company every month is 100 hours, equivalent to 6000 minutes.

$$d_6{}^+ + d_7{}^- - d_7{}^+ = JL \tag{9}$$

$$d_6{}^+ + d_7{}^- - d_7{}^+ = 600 \tag{10}$$

When:
$d_7{}^-$ = Variable deviation under overtime hours
$d_7{}^+$ = Variable deviation upper overtime hours
JL = Maximum capacity of overtime hours
The objective function is minimized overtime ($d_7{}^+$) :

$$Min\ Z = d_7{}^+ \tag{11}$$

3.2.4 Production cost constraint function. Production costs are costs used in the production process. These costs consist of raw material, labor, and overhead costs. Overhead costs are costing the company must incur outside the operational costs of production. The total production cost for the tp6 250 paving block is Rp. 43,016.00 per m/pcs of paving blocks produced, as well as the production of other types of paving blocks. The company has a limit that the capital issued is Rp. 150,000,000.00 per month. So the constraint function is designed as follows:

$$43016X_1 + 48516X_2 + 45216X_3 + 50716X_4 + 43016X_5 \leq 150000000 \tag{12}$$

$$43016X_1 + 48516X_2 + 45216X_3 + 50716X_4 + 43016X_5 + d_8{}^- - d_8{}^+ = 150000000 \tag{13}$$

Objective Function:

$$Min\ Z = d_8{}^+ \tag{14}$$

3.2.5 Raw material constraint function. The amount of raw material used for each product must be less than or equal to the availability of these raw materials. The formulation of the formula used is as follows:

When:
B = The amount of raw material used for each type of paving
x = The decision variable for the paving block type

BT = Amount of raw material availability
i = The type of Paving Block
l = The type of material (l = 1, 2, . . . 4)
B_1 = Amount of cement raw material usage
B_2 = Amount of sand raw material usage
B_3 = Amount of screening stone raw material usage
B_4 = Amount of use of stone ash raw materials

So, the formula for the constraint function of the use of raw materials to produce 1 m/pcs paving block every month is:

Objective Function:

Cement (Kg)

$$18X_1 + 22X_2 + 20X_3 + 24X_4 + 18X_5 \leq 128000 \quad (16)$$

Sand (m3)

$$0.0475X_1 + 0.0475X_2 + 0.0475X_3 + 0.0475X_4 + 0.0475X_5 \leq 840 \quad (17)$$

Screening stone (m3)

$$0.022X_1 + 0.022X_2 + 0.022X_3 + 0.022X_4 + 0.022X_5 \leq 840 \quad (18)$$

Stone ash (m3)

$$0.0273X_1 + 0.0273X_2 + 0.0273X_3 + 0.0273X_4 + 0.0273X_5 \leq 644 \quad (19)$$

Constrain:

$$18X_1 + 22X_2 + 20X_3 + 24X_4 + 18X_5 + d_9^- - d_9^+ = 128000 \quad (20)$$

$$0.0475X_1 + 0.0475X_2 + 0.0475X_3 + 0.0475X_4 + 0.0475X_5 + d_{10}^- - d_{10}^+ = 840 \quad (21)$$

$$0.022X_1 + 0.022X_2 + 0.022X_3 + 0.022X_4 + 0.022X_5 + d_{11}^- - d_{11}^+ = 840 \quad (22)$$

$$0.0273X_1 + 0.0273X_2 + 0.0273X_3 + 0.0273X_4 + 0.0273X_5 + d_{12}^- - d_{12}^+ = 644 \quad (23)$$

$$Min\ Z = \sum_{i=9}^{12} d_i^+ \quad (24)$$

3.2.6 Goal Programming Modeling Results. Production planning using LINGO is carried out in a monthly period. As a result, all objective functions are achieved. In addition, production costs in January also decreased by Rp. 50,780.680 from the monthly capital of Rp. 150,000,000.00 determined by the company. So, the calculation of the production planning resulted in a total cost reduction of Rp. 992,057,740.00 from Rp. 1,800,000,000.00 or equivalent to a 55.11% decrease in production costs.

In the model results obtained, there is still a large surplus of raw materials, and regular working and overtime hours have not been used. The company can modify the model if it wants to maximize its working hours to be more productive by adding existing restrictions.

4 4 CONCLUSION AND RECOMMENDATION

The results that can be concluded from this study are as follow:

1. Forecasting results using the Artificial Neural Network method provide an MSE error value accuracy rate of 0.017769 for Paving Block TP6 250 products in the upcoming 2022 period. The results of monthly demand forecasting in 2022 are in Table 4. The result of the ANN forecasting method can be continued for the following years.
2. The results of optimization of production planning using goal programming with LINGO show that all objective functions can be fulfilled. The four objective functions are the fulfillment of demand with the right quantity, the goal of normal working time, minimizing overtime hours, and minimizing production costs. Based on the calculation of the optimization of production planning using goal programming, there is a decrease in production costs in 1 year of Rp. 992,057,740.00 from the company's capital of Rp. 150,000,000.00 per month or equivalent to 55.11%. The formulation of the mathematical model that has been made can solve the same problem in the following periods. Production planning using the optimization method with goal programming is more useful and produces optimal solutions than production planning for the company's current condition

5 HISTORY DATES

In case of submissions being prepared for Journals or PACMs, please add history dates after References as (please note revised date is optional): Received July 2022; revised August 2022; accepted September 2022.

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REFERENCES

[1] Akbari, N., Jones, D., & Arabikhan, F. (2021). Goal programming models with interval coefficients for the sustainable selection of marine renewable energy projects in the UK. *European Journal of Operational Research*, 748-760.
[2] Anggraeni, W., Vinarti, R. A., Tyasnurita, R., & Permatasari, J. (2015). Production planning optimization using goal programming method in Habibah Busana. *Journal of Advanced Management Science, 3*(4), 270-275. doi:10.12720/joams.3.4
[3] Bose, J.-H., Flunkert, V., Gasthaus, J., Januschowski, T., Lange, D., Salinas, D., . . . Wang, Y. (2017). Probabilistic Demand Forecasting at Scale. *Proceedings of the VLDB Endowment, 10*(12), 1694-1705.
[4] Broza, D., Vanzettib, N., Corsano, G., & Montagnab, J. M. (2019). Goal programming application for the decision support in the daily production planning of sawmills. *Forest Policy and Economics*, 29-40.
[5] Defalque, C. M., Silva, A. F., & Marins, F. A. (2021). Goal programming model applied to waste paper logistics processes. *Applied Mathematical Modelling, 98*, 185-206.
[6] Ghalehkhondabi, I., Ardjmand, E., Weckman, G. R., & Young, W. A. (2015). An overview of energy demand forecasting methods. *Energy Systems, 8*(2), 411-447.
[7] He, W. R. (2020). Using of Artificial Neural Networks (ANNs) to predict the thermal conductivity of Zinc Oxide–Silver (50%–50%)/Water hybrid Newtonian nanofluid. *International Communications in Heat and Mass Transfer*, 104645.
[8] Hotniar, S. (2005). *Riset Operasional Seri Pemograman Linier.* Yogyakarta: Graha Ilmu.
[9] Işcan, B. (2020). ANN modeling for justification of thermodynamic analysis of experimental applications on combustion parameters of a diesel engine using diesel and safflower biodiesel fuels. *Fuel*, 118391.
[10] Jiang, L. L., & Maskell, D. L. (2015). Automatic Fault Detection and Diagnosis for Photovoltaic Systems using Combined Artificial Neural Network and Analytical Based Methods. *International Joint Conference on Neural Networks (IJCNN)* (pp. 1-8). Canada: IEEE.
[11] Kumar, C. A., & Srinivas, T. (2020). Using goal programming for transportation planning decisions problem Using goal programming for transportation planning decisions problem. *Materials Today: Proceedings.*

[12] Mardliyah, S., Fajar, M. Y., & Badruzzaman, F. H. (2022). Use of Forecasting and Goal Programming in Optimizing Rice Production Planning. *Bandung Conference Series: Mathematics. 2.* Bandung: Unisba. doi:https://doi.org/10.29313/bcsm.v2i1.2033

[13] Oliveira, W. A., Fiorotto, D. J., Song, X., & Jones, D. F. (2021). An extended goal programming model for the multiobjective integrated lot-sizing and cutting stock problem. *European Journal of Operational Research, 295*(3), 996-1007.

[14] Pujawan, I. N., & R, M. E. (2010). *Supply Chain Management.* Surabaya: Guna Widya.

[15] Renaldi, R. K., Marie, I. A., Moengin, P., W, N. J., & Nilla. (2021). Demand Forecasting Using Artificial Neural Networks and Production Planning Using Linear Programming in Aluminum Companies. *Jurnal Teknik Industri*, 196-203.

[16] Sari, I. R., & Sudiarso, A. (2015). Aggregate Production Planning Based on Demand Forecasting Using Artificial Neural Networks in IKM X. *Proc. SENTI-UGM*, (pp. 436-444). Yogyakarta.

[17] Sen, N., & Nandi, M. (2012). Goal programming, its application in management sectors–special attention into plantation management: a review. *nternational journal of scientific and research publications , 2*(9), 1-6.

[18] Setiawan, B. I., & Rusdiyanto. (2004). Neural Networks Application For River Flow Prediction. *Proceedings of the Simulation and Computing Technology Workshop and Applications.* Jakarta: BPPT.

[19] Sun, J., Zhao, Z., & Zhang, Y. (2011). Determination of three dimensional hydraulic conductivities using a combined analytical/neural network model. *Tunnelling and Underground Space Technology, 26*(2), 310–319.

[20] Taylor, S. J., & Letham, B. (2017). Forecasting at Scale. *The American Statistician, 72*(1), 37-45.

[21] Thike, P. H., Zhao, Z., Shi, P., & Jin, Y. (2020). ignificance of artificial neural network analytical models in materials' performance prediction. *Bulletin of Materials Science, 43*(1), 1-22.

Analysis of Waste Transportation Volume in Jakarta Province using Linear Regression and Random Forest Regression

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ABSTRACT

The accumulation of waste volume in the river waters of DKI Jakarta is still a significant problem that cannot be solved optimally because the population continues to increase every year, so the tonnage of waste also increases as well as some residents of DKI Jakarta still throw garbage into the river. In predicting the level of waste volume, the DKI Jakarta Provincial Environment Agency must make decisions, so it is necessary to carry out a prediction stage regarding the increase in waste in the future. For this reason, this research performs a prediction stage by utilizing two machine learning algorithms: Linear Regression and Random Forest Regression. The experiment used historical data on waste volume transportation from January to June 2021. The experimental results showed that the Random Forest Regression had the lowest error values of 0.82 and 0.81, with a training and testing data ratio of 80%:20%. On the other hand, Linear Regression has an error value of 0.83 and 0.82 at a ratio of 80%:20%. The analysis discussed in this study can be a reference for predicting and taking the necessary actions to prevent an increase in the volume of waste in DKI Jakarta Province.

CCS CONCEPTS

• **Computing methodologies**; • **Machine learning**;

KEYWORDS

Waste Transportation, Machine Learning, Linear Regression, Random Forest Regression

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1 INTRODUCTION

The waste problem in Jakarta, the capital of Indonesia, cannot be adequately solved because of high density of the population and at the same time continuously experience population growth from year to year. Thus, the tonnage of waste is increasing due to difficulties in managing waste piles [1]. Furthermore, the indifference of Jakarta residents to the environment leads to the cause of the tonnage of waste in Jakarta, which continues to increase yearly. Sources of waste are dominated by household, tourism, industrial, and marine waste in the small islands of Jakarta. The waste will usually end up in the Final Disposal Site (FDA), Temporary Disposal Site (TDS) and the sea or river [2]. Garbage thrown into the sea or rivers causes the garbage to end up on the beach so that it can cause the index of beaches/small islands in Indonesia to be "extremerly dirty" and lower the visitor acceptance index. As a result, plastic waste dominates the tourism sector in Jakarta, with a percentage value of 83.86% of the total waste [3]. This fact is further strengthened because the coastal environment in Indonesia's seas has been polluted by plastic waste, especially in Jakarta Bay, where the highest microplastic contamination is 37.440 - 38.790/kg resulting from dry weight particles [4].

Based on data from the National Waste Management Information System, Jakarta's waste in 2020 was 3,054,812.22 tons, while the amount in Jakarta in 2021 reached 3,083,437.85 tons [5]. In addition, from October to December 2021, the volume of waste transported from the Jakarta River reached 121,433.53 m3. Even though the tonnage of waste always increases yearly, people in Jakarta still live on polluted riverbanks. Therefore, the Jakarta Provincial Government's efforts to reduce the volume of waste in rivers are to budget IDR 1 trillion to normalize rivers and reservoirs in Jakarta and build a waste processing facility, namely the Intermediate Treatment Facility (ITF) [6]. This effort is very effective because, on February 7, 2021, the Provincial Government of Jakarta Province succeeded in reducing the volume of waste in the Jakarta River to 153.98 tons or 436 m3. The volume of this waste has decreased considerably compared to the volume on September 22, 2020, which amounted to 707.46 tons or around 2,033 m3. Therefore, in assisting the Jakarta Provincial Government in reducing the volume of waste from the river, a prediction method for the volume of waste transportation from Jakarta Rivers is required.

Kumar et al. [7] carry out research on the prediction of waste generation from residential areas in Vietnam using six machine learning algorithms, including Cubist Algorithm, k-Nearest Neighbors (k-NN), Artificial Neural Network (ANN), Linear Regression (LR), Random Forest (RF), and Support Vector Machine (SVM). The data for the experiments are taken from the Vietnam National

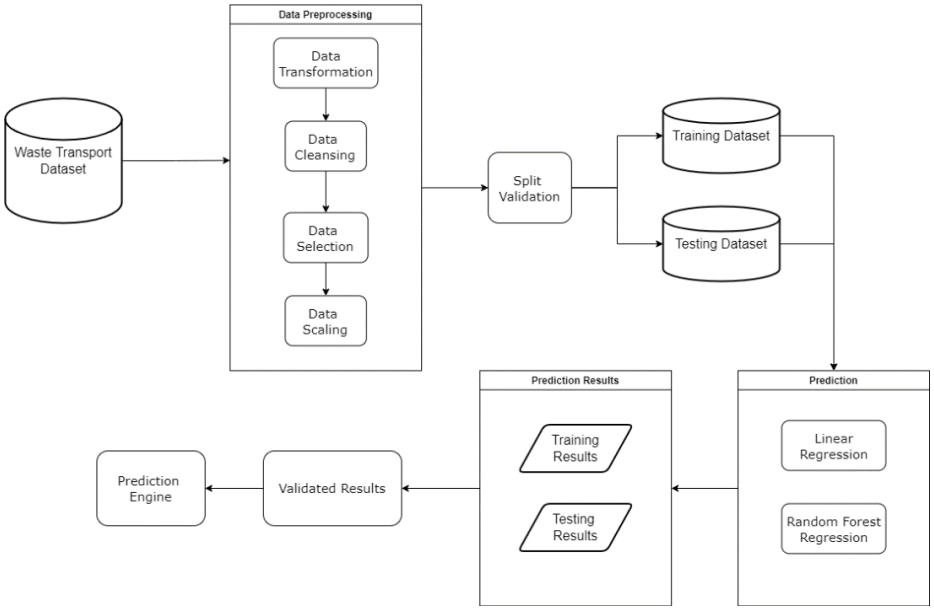

Figure 1: Research Flowchart in Predicting the Volume of Waste Transportation

Bureau of Statistics that covers eight independent variables with aspects of consumption, economy, demographics, and waste generation in residential areas, while the dependent variable is the amount of waste collected daily. The results of this study indicate that the k-NN and Random Forest algorithms have good predictive abilities with R2 metric prediction values of 0.96 and 0.97, respectively; and the error value indicated by the mean absolute error (MAE) metric is 121.5 and 125.0, respectively. These results indicate that the k-NN and Random Forest algorithms are very suitable for assisting the Vietnamese Government in predicting waste generation by improving their recycling practices.

Another study was conducted by Kannangara et al [8] on predicting the generation and diversion of regional municipal solid waste in Canada using two machine learning algorithms, i.e.: Decision Tree and ANN. The dataset used has been integrated with annual residential solid waste generation and paper transfer data from 220 cities in Ontario, Canada, along with socioeconomic data and demographic data based on the Canadian census program. The result of the study shows that the ANN produces a good accuracy value of 72%, while the decision tree algorithm only produces an accuracy value of 54%.

The main contribution of this research is a scheme to analyze and predict the volume of rivers waste transportation in Jakarta to assist the corresponding local agency in planning and managing the river waste in efficient manner.

2 RESEARCH METHODOLOGY

Figure 1 shows the proposed research design. It consists of four main modules, i.e.: Data Preprocessing, which includes data transformation, data cleansing, data selection, and data scaling; Split Validation; Prediction using Linear Regression (LR) and Random Forest Regression (RFR); and Validation of the prediction models and results. This study uses data from the Open Data Jakarta website from January to June 2021. The details of each module are explained in the following subsections.

2.1 Dataset Description

The data collected from the Open Data Jakarta website are grouped into 6 datasets by month (January, February, March, April, May, and June). Each dataset has a different number of rows, i.e.: 54343 for January data, 49252 for February data, 54715 for March data, 53100 for April data, 54870 for May data, and 53130 for June data. In addition, each dataset has 8 attributes, i.e.: month, point of waste collection location, sub-district, region, length or area of waste handling, unit length/area, date, and volume of waste per day in m^3 [9].

2.2 Data Preprocessing

Preprocessing is several steps needed before entering the machine learning modeling stage. The dataset will be prepared first, such as changing values and data types, cleaning data from missing or outlier values, selecting data, and scaling data values. [8].

2.2.1 Data Transformation. The transformation carried out in this study is to change the naming of attributes that were previously written in Indonesian to English. In addition, the next transformation is also carried out on the data values, precisely on the attribute of the volume of waste per day (m^3), which has the missing value converted into mean value.

2.2.2 Data Cleansing. At this stage, the data cleaning process is carried out on the value of outliers on the attribute volume of waste per day (m^3). In addition, it removes attributes that are not needed during the research, i.e.: month attribute.

2.2.3 Data Selection. Data selection is the stage of selecting attributes to serve as independent and dependent variables. In this study, the attribute date is the independent variable, and the attribute volume of waste per day (m^3) is the dependent variable.

2.2.4 Data Scaling. The last preprocessing carried out in this research is data scaling. Data scaling aims to overcome inconsistent data by making the data in the same range so that the resulting prediction results are accurate [10]. The scaling used in this study is a standard scaler where the data range for the average value is 0, and the standard deviation is 1 [11].

2.3 Split Validation

Split Validation is a process of selecting attributes for the independent and dependent variables and dividing randomly the data into two parts, namely training and testing data, based on the percentage of testing sizes that have been defined. In this study, the independent variable or predictor variable was selected based on the date of waste collected from several locations. In contrast, the volume of waste per day was the dependent or response variable [12].

2.4 Linear Regression

Linear Regression is a machine learning algorithm based on a supervised learning scheme that can predict between one or more independent variables (x) and one dependent variable (y) [13]. Both variables (independent and dependent variables) must consist of numerical data. The regression analysis output will conclude whether the independent variable has a linear relationship with the dependent variable. The basic formula for linear regression is represented in (1) [13].

$$Y = a + bX \tag{1}$$

Where:
Y: forecast value (dependent variable).a: intercept.b: slope.X: number of periods (Independent variable).

2.5 Random Forest Regression

Random Forest is one of the ensemble learning methods that can perform several tasks such as classification and regression. The ensemble learning method is based on the premise that it will produce much higher performance than other machine learning algorithms to solve real equation search problems by controlling predictive values to avoid overfitting [14]. The Random Forest Regression Algorithm is very suitable for non-linear modelling relationships between variables because it can overcome complex relationships between variables so that it will not be affected by multicollinearity [15]. The formula for Random Forest Regression is represented in (2) [16].

$$\mathrm{H}(\mathrm{x}) = \frac{1}{T}\sum_{i=1}^{T} \mathrm{h}_i(x) \tag{2}$$

Where:
T: number of regression trees.
hi(x): output of the i-th regression trees (hi) on sample x.

2.6 Mean Absolute Error

Mean Absolute Error (MAE) is a metric that can measure the absolute error of an average value between the predicted value and the actual value [17]. The formula for the mean absolute error is represented in (3) [18].

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n} |P_i - O_i| \tag{3}$$

Where:
Pi and Oi: estimated and observed values.
n: number of samples.

2.7 Mean Squared Error

Mean Squared Error (MSE) is a metric that can measure the difference in the average value obtained from the number of squared errors divided by the total number of predicted values, so this metric is very suitable to be used when weighting larger values for larger error values [19]. The formula for the mean squared error is represented in (4) [8].

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n} \left(\hat{Y}_i - Y_i\right) \tag{4}$$

Where:
n: number of samples
$\hat{Y}_i$: predicted values
Y_i: observed values

2.8 K-Fold Cross Validation

K-Fold Cross Validation is a cross-validation technique using a subset of data that has been randomized to test the success rate of a machine learning algorithm and can also be used in choosing which algorithm produces accurate accuracy values [20]. The randomized data subset consists of training and testing data where the subset has a predefined number of subsets (k value) [21]. Each k iteration is used for one testing data, and the rest is used as training data. The process is repeated until all data has been evaluated.

3 RESULT AND DISCUSSION

Differentiating the prediction results based on data distribution and data validation, each using outlier values and without using outlier values in the dependent variable. The reason why this experiment is distinguished based on the use of outlier values in the dependent variable is because by differentiating the experiment to determine the characteristics between the independent and dependent variables and the data points that affect the distribution of the relationship between the 2 variables used (independent variable from the date attribute and the dependent variable from attribute volume of waste per day) from the prediction results. The reason why this experiment is distinguished based on the use of outlier values in the dependent variable is because by differentiating the experiment to determine the characteristics between the independent and dependent variables and the data points that affect the distribution of the relationship between the 2 variables used (independent variable from the date attribute and the dependent variable from attribute volume of waste per day) from the prediction results.

Table 1: Split Validation Results without Outliers (January - February)

Algorithms	Data Train		Data Test		Data Train		Data Test	
	January				February			
	MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	1.57	2.98	1.59	3.07	0.97	1.16	0.96	1.16
Random Forest Regression	1.56	2.97	1.59	3.08	0.97	1.16	0.96	1.16

Table 2: Split Validation Results without Outliers (March – April)

Algorithms	Data Train		Data Test		Data Train		Data Test	
	March				April			
	MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	0.92	1.15	0.91	1.12	0.90	1.09	0.91	1.12
Random Forest Regression	0.92	1.15	0.91	1.12	0.90	1.09	0.91	1.12

Table 3: Split Validation Results without Outliers (May – June)

Algorithms	Data Train		Data Test		Data Train		Data Test	
	May				June			
	MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	0.83	0.82	0.83	0.82	1.17	1.74	1.17	1.71
Random Forest Regression	0.82	0.81	0.82	0.81	1.17	1.73	1.16	1.71

In addition, the prediction results will also be divided into six different months (from January to June), with the predicted output in the form of the volume of waste transported from January to June 2022. In this section, the prediction process is carried out with two algorithms, i.e.: Linear Regression and Random Forest Regression.

3.1 Split Validation Results

This section experiments with datasets from January to June. Each of these datasets will be divided into training and testing data with a total proportion of 80% to 20%. Training data is used to train the machine learning algorithms, and testing data is used after passing through the training process. In addition, experiments were also carried out on Linear Regression to see whether the independent variables had a positive linear relationship or not. This experiment is distinguished based on 2 differences in the dependent variable: without considering outlier and with considering outlier values.

Table 1, Table 2, and Table 3 exhibit the predicted results of waste transportation without outliers resulted in prediction error values per month transportation. The result is that May is the month with a lower error rate than the other five months, but when considering on the algorithm, Random Forest Regression provides much lower error values than Linear Regression with error values of 0.82 and 0.81.

Next, experiments using outliers in the dependent variable are carried out. The results obtained in Table 4, Table 5, and Table 6 show that June 2021 has an error rate of metrics MAE and MSE relatively low compared to the other five months. However, when considering on the algorithm, the Linear Regression dominantly provides lower prediction results compared to the Random Forest Regression with an error rate of 1.83 for the MAE metric in the training data and 1.81 for the MAE metric in the testing data. On the other hand, in the MSE metric for the training data, the Random Forest Regression has a low error rate compared to the Linear Regression, which is 10.37, while the prediction rate for the MSE metric in the testing data provides the same result, i.e.: 10.14.

3.2 Validation Results

Having done experimenting with data distribution based on a percentage of 80% training data and 20% testing data, the next step is to validate the prediction results using the k-fold cross-validation method. In addition, the validation process used in this study uses 3 different fold value scenarios, including 5-fold, 10-fold, and 15-fold. One of the advantages of using multiple k-fold value scenarios is to avoid bias and overfitting in the prediction results [22]. This experiment will also be differentiated based on 2 differences in the

Table 4: Split Validation Results using Outliers (January – February)

Algorithms	Data Train		Data Test		Data Train		Data Test	
	January				February			
	MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	3.20	19.12	3.30	21.72	2.27	25.97	2.26	20.67
Random Forest Regression	3.20	19.10	3.30	21.73	2.27	25.97	2.26	20.67

Table 5: Split Validation Results using Outliers (March – April)

Algorithms	Data Train		Data Test		Data Train		Data Test	
	March				April			
	MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	2.07	11.73	2.08	12.26	2.14	15.32	2.24	38.04
Random Forest Regression	3.20	19.10	2.08	12.28	2.14	15.31	2.24	38.03

Table 6: Split Validation Results using Outliers (May – June)

Algorithms	Data Train		Data Test		Data Train		Data Test	
	May				June			
	MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	2.02	12.13	2.02	11.30	1.83	10.38	1.81	10.14
Random Forest Regression	2.03	12.08	2.03	11.25	1.84	10.37	1.82	10.14

Table 7: Validation Results without Outliers (January – February)

Algorithms	K	Data Training		Data Testing		Data Training		Data Testing	
		January				February			
		MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear Regression	5	1.57	2.98	1.59	3.07	0.97	1.16	0.96	1.16
	10	1.57	2.98	1.59	3.07	0.97	1.16	0.96	1.16
	15	1.57	2.98	1.59	3.07	0.97	1.16	0.96	1.16
Random Forest Regression	5	1.56	2.98	1.58	3.07	0.97	1.16	0.96	1.16
	10	1.56	2.98	1.56	3.07	0.97	1.16	0.96	1.16
	15	1.56	2.98	1.56	3.07	0.97	1.16	0.96	1.16

dependent variable: without using outlier values and using outlier values.

Table 7, Table 8, and Table 9 show the validation results related to waste transportation per month without outlier values in the dependent variable. It can be concluded that the May dataset provides the lowest error values compared to the other five months. Even the error values obtained from the three k-fold values based on MAE and MSE metrics have the same ones obtained in the previous experiment (experiment with data distribution without outlier values). However, from the algorithm's perspective, Random Forest Regression obtain the lowest error values compared to Linear Regression where Random Forest Regression has error values of 0.82 and 0.81, while Linear Regression has error values of 0.83 and 0.82.

After validating without outlier values, the next step is to validate with outlier values in the dependent variable on the waste volume transportation data. Table 10, Table 11, and Table 12 show that June 2021 has a reasonably low error rate in predicting compared to the other five months, for both, the MAE and MSE metrics. However, when considering on the algorithm, Linear Regression has

Table 8: Validation Results without Outliers (March – April)

Algorithms	K	Data Training		Data Testing		Data Training		Data Testing	
		March				April			
		MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear	5	0.92	1.15	0.90	1.12	0.90	1.09	0.91	1.12
Regression	10	0.92	1.15	0.90	1.12	0.90	1.09	0.91	1.12
	15	0.92	1.15	0.90	1.12	0.90	1.09	0.91	1.12
Random Forest	5	0.92	1.15	0.91	1.13	0.90	1.09	0.91	1.13
Regression	10	0.92	1.15	0.92	1.13	0.90	1.09	0.90	1.13
	15	0.92	1.15	0.92	1.13	0.90	1.09	0.90	1.13

Table 9: Validation Results without Outliers (May – June)

Algorithms	K	Data Training		Data Testing		Data Training		Data Testing	
		May				June			
		MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear	5	0.83	0.82	0.83	0.82	1.17	1.74	1.16	1.71
Regression	10	0.83	0.82	0.83	0.82	1.17	1.74	1.16	1.71
	15	0.83	0.82	0.83	0.82	1.17	1.74	1.16	1.71
Random Forest	5	0.82	0.81	0.82	0.81	1.17	1.74	1.16	1.71
Regression	10	0.82	0.81	0.82	0.81	1.17	1.74	1.17	1.71
	15	0.82	0.81	0.82	0.81	1.17	1.73	1.17	1.71

Table 10: Validation Results using Outliers (January – February)

Algorithms	K	Data Training		Data Testing		Data Training		Data Testing	
		January				February			
		MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear	5	3.20	19.12	3.38	21.69	2.27	25.97	2.24	20.69
Regression	10	3.20	19.12	3.38	21.69	2.27	25.97	2.24	20.68
	15	3.20	19.12	3.38	21.69	2.27	25.97	2.24	20.68
Random Forest	5	3.20	19.13	3.38	21.77	2.27	25.98	2.25	20.79
Regression	10	3.20	19.14	3.20	21.76	2.27	25.99	2.27	20.75
	15	3.20	19.13	3.20	21.76	2.27	25.99	2.27	20.75

good validation results compared to the Random Forest Regression algorithm.

In addition, the results of the three scenarios show that the k-fold value in the MAE metric with training data has the same predictive value as the results obtained in the previous experiment (experiment with data distribution using outlier values), i.e.: 1.83 for Linear Regression and 1.84 for Random Forest Regression. Furthermore, the same results were also obtained from the three scenarios of the k-fold value with a linear regression algorithm which produced a predictive value in the MSE metric of 10.14 on the testing data. Furthermore, the MSE metric with the Linear Regression algorithm also shows the same predictive value as the previous experiment (experiment with data distribution using outlier values), which is 10.38. On the other hand, the Forest Random Regression algorithm shows a different predictive value from the previous experiment, i.e.: 10.39.

The difference in the predicted value is also found in the MSE metric with the testing data because the three scenarios of the k-fold value get a predictive value of 10.15. While the prediction value of 10.14 was obtained in the previous experiment (experiment with data distribution using outlier values). Furthermore, the three scenarios of the k-fold value in the MAE metric with training data in Linear Regression show different predictive values from the previous experiment because the predictive value from the validation results is 1.80, while the predictive value from the previous experiment is 1.81. Meanwhile, the Random Forest Regression algorithm with a 5-fold value provides different results from the other two k-fold scenarios, where the predicted value generated in the 5-fold scenario is 1.85, and the other two scenarios (10-fold and 15-fold) is 1.84.

Table 11: Validation Results using Outliers (March – April)

Algorithms	K	Data Training		Data Testing		Data Training		Data Testing	
		March				April			
		MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear	5	2.07	11.73	2.09	12.26	2.14	15.33	2.30	38.03
Regression	10	2.07	11.74	2.09	12.26	2.14	15.33	2.30	38.05
	15	2.07	11.74	2.09	12.27	2.14	15.33	2.30	38.03
Random Forest	5	2.07	11.74	2.09	12.31	2.14	15.33	2.29	38.15
Regression	10	2.07	11.74	2.07	12.32	2.14	15.34	2.14	38.15
	15	2.07	11.74	2.07	12.30	2.14	15.34	2.14	38.13

Table 12: Validation Results using Outliers (May – June)

Algorithms	K	Data Training		Data Testing		Data Training		Data Testing	
		May				June			
		MAE	MSE	MAE	MSE	MAE	MSE	MAE	MSE
Linear	5	2.02	12.13	2.01	11.30	1.83	10.38	1.80	10.14
Regression	10	2.02	12.13	2.01	11.30	1.83	10.38	1.80	10.14
	15	2.02	12.13	2.01	11.30	1.83	10.38	1.80	10.14
Random Forest	5	2.03	12.10	2.03	11.31	1.84	10.39	1.85	10.15
Regression	10	2.03	12.10	2.03	11.30	1.84	10.39	1.84	10.15
	15	2.03	12.10	2.03	11.28	1.84	10.39	1.84	10.15

3.3 Discussion

This section describes whether the independent and dependent variables have a positive slope or not based on the prediction results shown in the Linear Regression graph using the May 2021 data because the prediction results with the May data have a lower error rate than the other five months without outlier values. In addition to the Linear Regression graphs, this section also discusses the prediction results in line graphs generated by the Random Forest Regression algorithm without outlier values.

Previously, the amount of data in the May dataset was 54870 data. However, as many as 6096 data were indicated as outlier values and were omitted from the data, leaving only 48774 data. In addition, the correlation between the date attribute and the volume of waste per day in the May dataset is not good enough, which is only 0.017, indicating that the data used in the experiment is not suitable for implementation using Linear Regression algorithm. Figure 2 shows the correlation value between the date attribute and the waste volume attribute per day.

Therefore, the linear graph of the experimental results without outlier values shows that the independent and dependent variables do not have a positive linear slope but a zero slope. The zero slopes are caused by the coordinates of the dependent variable (y) do not change when the coordinates of the independent variable (x) change.

Figure 3 shows the prediction results with linear graphs on experiments without outlier values for the May data with a linear regression algorithm that does not have a positive linear slope but zero slopes (horizontal line). So, the discussion results based on experiments without outlier values using a linear regression algorithm on the waste transportation volume dataset in May still

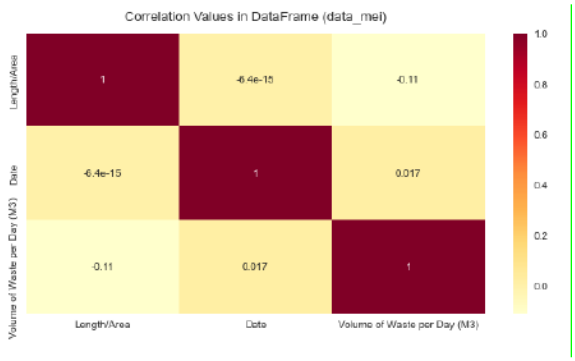

Figure 2: Correlation Values in May Dataset

resulted in zero slopes, indicated by a horizontal line in testing data in Figure 3 lies in the distribution of data points and the location of the linear line because, without outlier values, the distribution of data points is spread over several parts horizontally followed by a horizontal line. This means that 6.096 data that have been removed from the dependent variable because they are indicated as outlier values are very influential in placing the data points along with the horizontal linear line.

The subsequent discussion will explain the prediction results from Random Forest Regression without outlier values in the dependent variable based on May data. Figure 4 shows a downward line graph so that it can be concluded that the MAE and MSE metrics error rate in predicting the volume of waste transport data for May is very small. In addition, Figure 4 also shows that the tonnage of

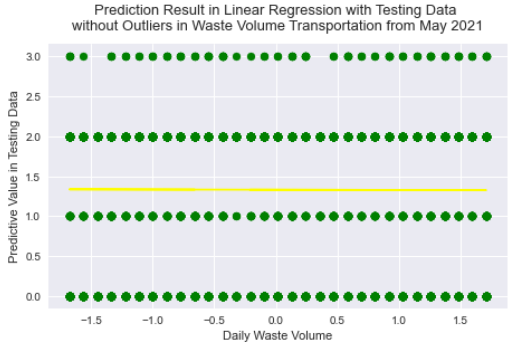

Figure 3: Prediction using Linear Regression for Testing Data without Outliers

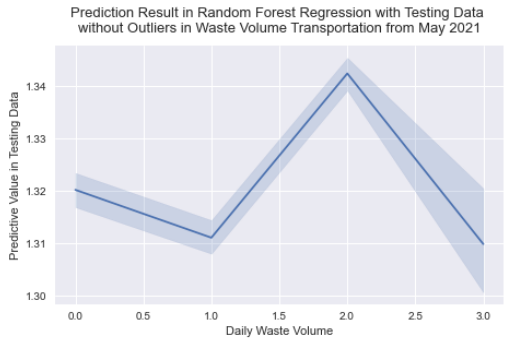

Figure 4: Prediction Result on Random Forest for Testing Data with Outliers

waste to be transported from the waters of the DKI Jakarta river in May 2022 will be much less than in 2021.

4 CONCLUSION

Experimental results showed that Random Forest Regression performed better compare to the Linear Regression, due to Random Forest Regression produces the lowest error value compared to Linear Regression. The error values for Random Forest Regression are 0.82 and 0.81, while the error values for Linear Regression are 0.83 and 0.82. Moreover, among the six datasets used in this study, the month of May dataset provided the best performance model. The month of May dataset produced the lowest error value for both Linear Regression and Random Forest Regression. This research provided useful insights with regards to the transportation of waste volumes in Jakarta area. Experimental results reveal the usefulness of Linear Regression and Random Forest Regression algorithms as a reference for further research on the transportation of waste volumes in the rivers of Jakarta Province in the future.

REFERENCES

[1] A. Brotosusilo, S. H. Nabila, H. A. Negoro, and D. Utari, "The level of individual participation of community in implementing effective solid waste management policies," *Global Journal of Environmental Science and Management*, vol. 6, no. 3, pp. 341–354, 2020, doi: 10.22034/gjesm.2020.03.05.

[2] Y. A. Hidayat, S. Kiranamahsa, and M. A. Zamal, "A study of plastic waste management effectiveness in Indonesia industries," *AIMS Energy*, vol. 7, no. 3, pp. 350–370, 2019, doi: 10.3934/ENERGY.2019.3.350.

[3] Y. Hayati, L. Adrianto, M. Krisanti, W. S. Pranowo, and F. Kurniawan, "Magnitudes and tourist perception of marine debris on small tourism island: Assessment of Tidung Island, Jakarta, Indonesia," *Marine Pollution Bulletin*, vol. 158, no. June, p. 111393, 2020, doi: 10.1016/j.marpolbul.2020.111393.

[4] P. Lestari and Y. Trihadiningrum, "The impact of improper solid waste management to plastic pollution in Indonesian coast and marine environment," *Marine Pollution Bulletin*, vol. 149, no. August, p. 110505, 2019, doi: 10.1016/j.marpolbul.2019.110505.

[5] "SIPSN - Sistem Informasi Pengelolaan Sampah Nasional." https://sipsn.menlhk.go.id/sipsn/public/data/komposisi (accessed Jun. 06, 2022).

[6] F. Hermawan, "Optimization Of Transportation of Municipal Solid Waste from Resource to Intermediate Treatment Facility with Nearest Neighbour Method (Study on six Sub Sub District in DKI Jakarta Province)," *JOURNAL OF ENVIRONMENTAL SCIENCE AND SUSTAINABLE DEVELOPMENT*, vol. 1, no. 1, Dec. 2018, doi: 10.7454/jessd.v1i1.21.

[7] X. C. Nguyen *et al.*, "Development of machine learning - based models to forecast solid waste generation in residential areas: A case study from Vietnam," *Resources, Conservation and Recycling*, vol. 167, no. July 2020, p. 105381, 2021, doi: 10.1016/j.resconrec.2020.105381.

[8] M. Kannangara, R. Dua, L. Ahmadi, and F. Bensebaa, "Modeling and prediction of regional municipal solid waste generation and diversion in Canada using machine learning approaches," *Waste Management*, vol. 74, pp. 3–15, 2018, doi: 10.1016/j.wasman.2017.11.057.

[9] "Data Volume Pengangkutan Sampah di Kali Sungai Situ Waduk Tahun 2021 - Open Data Jakarta." https://data.jakarta.go.id/dataset/data-volume-pengangkutan-sampah-di-kali-sungai-situ-waduk-tahun-2021 (accessed Jun. 08, 2022).

[10] V. N. G. Raju, K. P. Lakshmi, V. M. Jain, A. Kalidindi, and V. Padma, "Study the Influence of Normalization/Transformation process on the Accuracy of Supervised Classification," *Proceedings of the 3rd International Conference on Smart Systems and Inventive Technology, ICSSIT 2020*, no. Icssit, pp. 729–735, 2020, doi: 10.1109/ICSSIT48917.2020.9214160.

[11] S. Ray, "A Quick Review of Machine Learning Algorithms," Proceedings of the International Conference on Machine Learning, Big Data, Cloud and Parallel Computing: Trends, Prespectives and Prospects, COMITCon 2019, pp. 35–39, 2019, doi: 10.1109/COMITCon.2019.8862451.

[12] W. M. Baihaqi, M. Dianingrum, K. A. N. Ramadhan, and T. Hariguna, "Linear regression method to model and forecast the number of patient visits in the hospital," *Proceedings - 2018 3rd International Conference on Information Technology, Information Systems and Electrical Engineering, ICITISEE 2018*, pp. 247–252, 2018, doi: 10.1109/ICITISEE.2018.8720979.

[13] P. Dong, H. Peng, X. Cheng, Y. Xing, X. Zhou, and D. Huang, "A Random Forest Regression Model for Predicting Residual Stresses and Cutting Forces Introduced by Turning IN718 Alloy," *2019 IEEE International Conference on Computation, Communication and Engineering, ICCCE 2019*, pp. 5–8, 2019, doi: 10.1109/ICCCE48422.2019.9010767.

[14] I. Ouedraogo, P. Defourny, and M. Vanclooster, "Application of random forest regression and comparison of its performance to multiple linear regression in modeling groundwater nitrate concentration at the African continent scale," *Hydrogeology Journal*, vol. 27, no. 3, pp. 1081–1098, 2019, doi: 10.1007/s10040-018-1900-5.

[15] H. Liu, Q. Li, D. Yu, and Y. Gu, "Air quality index and air pollutant concentration prediction based on machine learning algorithms," *Applied Sciences (Switzerland)*, vol. 9, no. 19, 2019, doi: 10.3390/app9194069.

[16] Q. Quan, Z. Hao, H. Xifeng, and L. Jingchun, "Research on water temperature prediction based on improved support vector regression," *Neural Computing and Applications*, vol. 4, 2020, doi: 10.1007/s00521-020-04836-4.

[17] X. Xie *et al.*, "Comparison of random forest and multiple linear regression models for estimation of soil extracellular enzyme activities in agricultural reclaimed coastal saline land," *Ecological Indicators*, vol. 120, no. June 2020, p. 106925, 2021, doi: 10.1016/j.ecolind.2020.106925.

[18] U. Ahmed, R. Mumtaz, H. Anwar, A. A. Shah, and R. Irfan, "Efficient Water Quality Prediction Using Supervised Machine Learning," *Water (Basel)*, vol. 11, no. 1, pp. 1–14, 2019.

[19] B. G. Marcot and A. M. Hanea, "What is an optimal value of k in k-fold cross-validation in discrete Bayesian network analysis?," *Computational Statistics*, vol. 36, no. 3, pp. 2009–2031, 2021, doi: 10.1007/s00180-020-00999-9.

[20] A. Bayhaqy, S. Sfenrianto, K. Nainggolan, and E. R. Kaburuan, "Sentiment Analysis about E-Commerce from Tweets Using Decision Tree, K-Nearest Neighbor, and Naïve Bayes," *2018 International Conference on Orange Technologies, ICOT 2018*, no. November 2019, 2018, doi: 10.1109/ICOT.2018.8705796.

[21] M. Hasnain, M. F. Pasha, I. Ghani, M. Imran, M. Y. Alzahrani, and R. Budiarto, "Evaluating Trust Prediction and Confusion Matrix Measures for Web Services Ranking," *IEEE Access*, vol. 8, pp. 90847–90861, 2020, doi: 10.1109/ACCESS.2020.2994222.

Influence of the Knowledge of Procurement Personnel on Implementation of Green Public Procurement

(Case Study: Banten, East Java, and Central Java Provinces)

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ABSTRACT

Traditionally, public procurement practices emphasize value for money, which is carried out through competitive tenders to ensure that government agencies receive the cheapest offers of goods/services. But it should not only consider economic factors; the public procurement in Indonesia is also expected not to damage the environment. However, the weak capability and knowledge of personnel causes the implementation of green procurement in government institutions has not shown significant progress.

The purpose of this study is to find out what factors will be able to increase the performance of green procurement in government institutions. This study uses data from questionnaires distributed to 43 respondents from Banten, East Java, and Central Java Provinces and tests using multiple linear regression methods and Moderated Regression Analysis (MRA). Data processing shows that the awareness of procurement personnel regarding the implementation of green public procurement, training and individual awareness has a significant effect to the performance of green public procurement. In addition, training and the joining in procurement association strengthen the relationship between awareness of procurement personnel regarding to the implementation of green procurement toward performance of green public procurement. This is importance to develop personnel knowledge through training and joining procurement associations. In this way, personnel awareness regarding implementation of green procurement is able to further improve green public procurement performance.

CCS CONCEPTS

• :; • **Social and professional topics** → Computing / technology policy; Government technology policy; Governmental regulations;

KEYWORDS

Green Public Procurement, Knowledge

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1 INTRODUCTION

The procurement of goods and services is a set of activities carried out by the public and private sectors. Based on the criteria written in Presidential Regulation no. 16 of 2018 concerning Government Procurement of Goods/Services, government procurement of goods and services represents no less than 50% of the State Budget [1]. With the large number of costs budgeted for procuring goods and services, the procurement process is considered to receive significant attention for its role in impacting the environment. The procurement process from operation to completion dramatically affects the background, so it is necessary to pay attention to every function in the manufacture of goods to be held.

One aspect of sustainable procurement is the environmental factor, which is referred to as green procurement. In the public sector, it is known as Green Public Procurement. Green Public Procurement is a procurement process adopted by the government to encourage all sectors to implement environmentally friendly design and manufacturing to reduce the environmental impact of purchased products throughout their life cycle. As the final buyer in government procurement of goods and services, procurement personnel play an essential role in the implementation of Green Public Procurement [2]. The low implementation of Green Public Procurement is a question because this regulation was introduced since 2010.

Therefore, improving the performance of Green Public Procurement is very important for Indonesia, especially the Bureau of Procurement of Goods and Services on the island of Java, to preserve the environment and continue to promote sustainable development. In addition, Green Public Procurement is expected to encourage and spur the private sector to be more aware of the importance of environmentally friendly procurement. This study uses a causal study research design that looks at the relationship of independent variables to the implementation of Green Public Procurement. Respondents that will be used are the tender commitee at the Government Procurement Bureau in Banten, Central Java, and East Java Provinces. The tender commitee was chosen as the respondent in this study because it has the authority to review the specifications of goods or services offered by PPK.

2 LITERATURE REVIEW

2.1 Green Public Procurement

Green Public Procurement is an approach used to integrate the existing criteria in environmental preservation into all aspects of procurement activities, which is expected to be a driver of product and technological innovation-oriented towards ecological protection throughout the product life cycle [3].

Environmentally friendly procurement is one of the initiatives introduced to improve sustainability. Thus, Green Public Procurement is considered a new link between environmental and economic factors in procuring goods and services. However, the process towards a more environmentally friendly procurement requires a reconceptualization of the procurement process, from the level of decision-makers who initially only considered the economy, now have to consider environmental factors as well. For this reason, Green Public Procurement is an instrument that gives the initiative to suppliers in their product offering process to prioritize ecological factors in the tender process [4].

2.1.1 Green Public Procurement in Indonesia. In Indonesia, goods and services that are environmentally sound are regulated by two regulations, namely the Minister of Environment Regulation no. 8 of 2010 concerning Criteria and Certification of Environmentally Friendly Buildings and Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.30/Menlhk/Setjen/PHLP.3/3/2016 concerning Performance Assessment of Sustainable Production Forest Management and Timber Legality Verification for Permit Holders, Rights Management, or Private Forests. In South Kalimantan Province, it has begun to issue Governor Regulation (Pergub) No. 093 concerning Green Public Procurement to support the Green Revolution in South Kalimantan Province, later abbreviated as G-PRO.

It can be concluded that the implementation of Green Public Procurement in Indonesia is still in the introduction stage. Although Green Public Procurement has started to be implemented, in reality, its absorption is still deficient. Green Public Procurement has started on paper commodities by looking for paper that already has eco-labeling. In addition, the government has made environmentally friendly procurement in the furniture sector. However, its implementation is still minimal. Stakeholders face various challenges such as lack of knowledge and awareness about the concept of green procurement [5].

2.1.2 Implementation of Green Public Procurement at Individual Level. The Green Public Procurement policy aims to reduce the environmental impact of services and products throughout their life cycle [6]. There are still many government procurement personnel at the city government level, especially in developing countries that do not yet have the human resources to do this, so it is necessary to use various indicators and environmentally friendly labels. But again, that stakeholders face multiple challenges such as lack of knowledge and awareness about the concept of green procurement. The lack of knowledge among procurement personnel is a significant challenge in implementing environmentally friendly procurement [3, 7–9]. The people's lack of understanding and knowledge is an obstacle in implementing green procurement [10].

2.2 Linear Regression Analysis and Moderate Regression Analysis

Regression analysis is an analytical tool used to see the relationship between the independent variable and the dependent variable and predict a variable [11]. Multiple linear regression analysis is the right analytical tool to use to determine the relationship or influence of two or more independent variables on the dependent variable [11].

Multiple linear regression is used when testing the effect of two or more dependent variables on the dependent variable, which is described by a mathematical equation. The purpose of doing multiple linear regression analysis is to estimate the interaction of the independent variable on the dependent variable. The following is a mathematical model of multiple linear regression:

$Y = \alpha 0 + \alpha 1\ X1 + \alpha 2\ X2 + \ldots + \alpha k\ Xk + e$

refers:

Y = dependent;

$\alpha 0, \ldots, \alpha k$ = regression coefficient,

X1,..., Xk = independent variable

E = error

Moderated Regression Analysis (MRA) is carried out when testing a model that has an interaction element (multiplication of two or more independent variables) [12]. The purpose of the MRA test is to see whether a variable strengthens or weakens the relationship between the independent variable and the dependent variable [13]. The following is a mathematical model of MRA:

$Y = a + b1X1 + b2X2 + b3X1X2 + e$

3 RESEARCH METHODOLOGY

The following is the research flow in this research:

- Preliminary study (literature study and field study)
- Determination of research questions
- Research design

This research is included in the category of causal studies because the research focuses on looking at the impacts or effects that occur by looking for the cause of these impacts. In this case, the influence or effect is the dependent variable or the performance of green public procurement. In sample collection, the technique used is purposive sampling or a sampling technique that must be based on several considerations [14].

The purpose of this study is to prove the cause-and-effect relationship of several variables. The dimension used in this research is the time dimension of cross-sectional design. The single cross-sectional design is data collection that is carried out only once at a specific time. The researcher uses a single cross-sectional design type because the research will only look at the phenomenon in one research period.

- Research variable

This research variable is based on previous research taken from several journals. Research [15, 16] used all factors in the journal, including: awareness of green public procurement implementation policies, understanding of procurement personnel regarding regulations related to green public procurement, training on green

Table 1: Characteristics of Respondents

Characteristics	Categori	Number of Respondents
Respondent Age	26 – 30 years	2 (5%)
	31 – 35 years	8 (19%)
	36 – 40 years	16 (37%)
	41 – 45 years	10 (23%)
	46 – 50 years	5 (12%)
	51 – 55 years	2 (5%)
Length of Working Time as Procurement Personnel	1 – 5 years	11 (26%)
	6 – 10 years	13 (30%)
	11 – 15 years	9 (21%)
	16 – 20 years	8 (19%)
	>20 years	2 (5%)
Workplace	Biro PBJ Banten Province	14 (33%)
	Biro PBJ Central Java Province	13 (30%)
	Biro APBJ Jawa Tengah Province	16 (37%)

public procurement, joining procurement associations, and implementation of green public procurement. At research [17] are cross-departmental management, individual awareness, and top-level management support. And in study [18–20] the factor used is upper management support.

- Research Instruments
- Data Collection and Data Analysis

The data was obtained through filling out questionnaires directly to the respondents, namely members of the tender commitee at the Bureau of Procurement of Goods and Services in the Provinces of Banten, Central Java, and East Java. The responses given by respondents through questionnaires will be the primary data in the study and processed using multiple linear regression and Moderated Regression Analysis (MRA).

- Conclusions and suggestions

4 ANALYSIS AND DISCUSSION

4.1 Characteristics of Respondents

Data collection is done by distributing online questionnaires, a list of statements regarding the knowledge factors that encourage the implementation of green public procurement. The distribution of the questionnaire was carried out using a google form. The total number of respondents who filled out the questionnaire was 43 POKJA. The main reason is that the green procurement policy is a national policy that all government institutions must implement to procure goods/services. Respondents used in this study include PBJ Banten, PBJ East Java, and APBJ Central Java. Table 1 shows the characteristics of respondents as below.

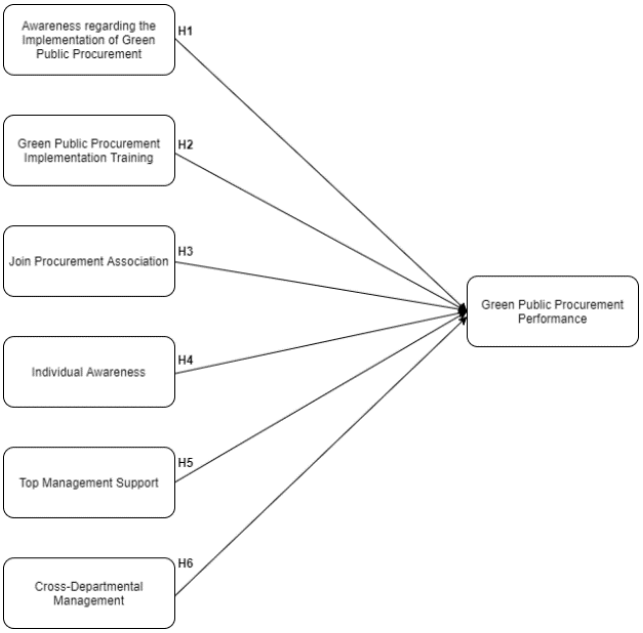

Figure 1: Multiple Regression Analysis Model

4.2 Validity and Reliability Test

Validity and reliability tests were conducted using 24 respondents. The purpose of the validity test is to ensure that the indicators of each variable used in this study are valid. The questionnaire is considered good when the value of rtable > rcount [13]. While the reliability test was conducted to determine whether the answers to each research instrument used had the same data at different times. The questionnaire is considered reliable when the Cronbach Alpha value of the device has a value of more than 0.60 [13].

In this study, the indicator is considered valid because the rcount results of all research indicators are above the rtable value. Likewise with the reliability test, all variables are considered reliable because Cronbach's Alpha value is above 0.60.

4.3 Hypothesis Testing

Figure 1 is the multiple regression analysis model that shows the factors that affect performance of green public procurement.

The following Table 2 shows the results of multiple linear regression:

A determination test is used to determine the contribution of the independent variables (independent) together in explaining the dependent variable (dependent) or how much influence the independent variables simultaneously have on the dependent variable. The adjusted r square is 0.661, which means that 66.1% of the implementation of green public procurement is influenced by awareness of procurement personnel regarding the implementation of green public procurement, training on green public procurement, joining of procurement personnel in procurement associations, individual attention, cross-departmental management, and support. top management and the other 33.9% are influenced by other variables not examined in this study.

Table 2: Coefficient of Determination Test

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.842[a]	.710	.661	1.145	2.468

Table 3: Multiple Linear Regression F Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	115.444	6	19.241	14.673	.000[b]
	Residual	47.207	36	1.311		
	Total	162.651	42			

Table 4: Multiple Linear Regression Hypothesis Output

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
	B	Std Error	Beta		
(Constant)	-2.706	2.174		-1.245	0.221
Awareness	0.423	0.154	0.306	2.754	0.09
Training	0.575	0.205	0.380	2.804	0.08
Join Assoc	-0.116	0.177	-0.089	-0.656	0.516
Cross Dept	0.113	0.285	0.042	0.398	0.693
Individual awareness	0.248	0.080	0.345	3.116	0.04
Top Mgt Support	0.284	0.089	0.330	3.194	0.03

In Table 3. it is shown that the multiple regression test shows the calculated F result of 14,673 with a significance level of 0.000 which is smaller than 0.05, where the calculated F value is 14.673 greater than the F table value, which is 2.37 (f (k; nk), F = (6; 36)). This means that the variables of awareness of procurement personnel regarding the implementation of green public procurement, training on green public procurement, the joining of procurement personnel in procurement associations, individual awareness, cross-departmental management, and top-level management support together affect the implementation of green public procurement.

From the output above in Table 4, it can be concluded that the hypothesis is as follows:

- H1: Awareness of procurement personnel regarding the implementation of green public procurement has a positive and significant impact on the performance of green public procurement.

The results of SPSS processing, H1 has a tcount of 2.754 with a significance value of 0.009. In this study, it can be seen that H1 is acceptable, meaning that there is a significant and positive influence between the awareness of procurement personnel regarding the implementation of green public procurement (X1) on the performance of green public procurement.

The results in this study are in line with previous research that stated that the awareness of procurement personnel regarding the implementation of green public procurement influences the performance of green public procurement [15]. This is also reinforced by a study that says that higher self-awareness of guidelines/regulation awareness positively affects green public procurement performance [16, 21].

- H2: Training on the implementation of green public procurement has a positive and significant impact on the performance of green public procurement.

In the results of SPSS processing, H2 has a tcount value of 2.804 with a significance of 0.008. In this study, it can be seen that H2 can be accepted because there is a significant and positive effect between training on the implementation of green public procurement (X3) on the performance of green public procurement.

The results in this study are in line with previous research, which states that training on the implementation of green public procurement influences the performance of green public procurement [16, 22]. This also supports the assertion that training on green public procurement plays an essential role in promoting the implementation of green public procurement [23]. There are more training and workshops on sustainable procurement, thimplementation of green public procurement will also improve.

- H3: The joining of Procurement Personnel in the Procurement Association has a positive and significant impact on the performance of green public procurement.

The results of SPSS processing, H3 have a tcount value of -0.656 with a significance of 0.516. In this study, it can be seen that H3 cannot be accepted because there is no significant effect at the 5% significance level between the joining of procurement personnel in procurement associations (X4) on the implementation of green public procurement.

The results in this study are in line with previous research, which states that the joining of procurement personnel in procurement associations does not affect the implementation of green public procurement [15]. Not all procurement personnel are members of procurement associations, thus reducing the impact of joining procurement personnel in procurement associations on the implementation of green public procurement.

- H4: Cross-departmental management has a positive and significant impact on the performance of green public procurement.

The results of SPSS processing, H4 have a tcount value of 0.398 with a significance of 0.693. In this study, it can be seen that H4 cannot be accepted because there is no significant effect at the 5% significance level between cross-departmental management (X5) on the implementation of green public procurement.
The results in this study are not in line with previous research that states that cross-departmental management influences the implementation of green public procurement [24]. Based on the results of interviews conducted in the field, the difference in results due to collaboration and formal internal communication has never been made. However, informal communication has happened to some respondents, but it only happened to the extent that it had happened but was not implemented in reality. In addition, what makes the results of this study different is that the research was conducted in Australia, where the characteristics of the country and procurement personnel are also definitely other so that different results may occur.

- H5: Individual awareness has a positive and significant impact on the performance of green public procurement.

The results of SPSS processing, H5 have a tcount value of 3.116 with a significance of 0.004. In this study, it can be seen that H5 can be accepted because there is a significant and positive influence between individual awareness (X6) on the implementation of green public procurement.
The results in this study are in line with previous research that states that individual awareness influences the implementation of green public procurement [16, 22]. The personal attitude applied will have an impact on the procurement process carried out [25], so it is excellent if procurement personnel have a tremendous individual awareness of environmentally oriented procurement.

- H6: Top management support has a positive and significant impact on the performance of green public procurement.

The results of SPSS processing, H6 have a tcount value of 3.194 with a significance of 0.003. In this study, it can be seen that H6 can be accepted because there is a significant and positive influence between top management support (X7) on the implementation of green public procurement.
H The results in this study are in line with previous research that states that upper management support influences the implementation of green public procurement [20]. By providing direct support in the form of political commitment, environmental knowledge, a better organizational structure, and a focus on regulatory interpretation will influence the implementation of green public procurement [19].

Table 5: Output Moderated Regression Analysis (MRA)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.349	1.802		3.524	.001
	X1	.183	.305	.132	.602	.551
	Moderasi1	.017	.011	.309	1.645	.108
	Moderasi2	.087	.025	.788	3.512	.001
	Moderasi3	-.050	.020	-.508	-2.515	.016

a. Dependent Variable: Y

Figure 2 is the moderated regression analysis model that shows the factors that moderate the affect of awareness regarding the implementation of green public procurement toward performance of green public procurement.

Table 5 shows the output of the Moderated Regression Analysis perhitungan (MRA):

- H1a: Procurement Personnel Awareness Regarding Green Public Procurement Regulations/Regulations positively moderates the effect of Procurement Personnel Awareness on Green Public Procurement Implementation.

The result of SPSS processing, H1a has a significance value of 0.108, more significant than 0.05. In this study, it can be seen that H1a cannot be accepted because there is no significant effect at the 5% significance level that Procurement Personnel Awareness Regarding Regulations/Regulations of Green public procurement (X2) does not have a positive impact/does not strengthen the relationship Awareness of procurement personnel regarding the implementation of green public procurement on the performance of green public procurement. The results in this study are in line with previous research, which states that Awareness of Procurement Personnel Regarding Regulations/Regulations of green public procurement does not have a positive effect/does not strengthen the relationship between green public procurement implementation [26]. This means that knowledge of regulations and regulations on green public procurement is not an essential factor in the performance of environmentally friendly procurement.

- H1b: Training on Green public procurement positively moderates the effect of Procurement Personnel Awareness on the Implementation of green public procurement.

The result of SPSS processing, H1b has a significance value of 0.001. This indicates that H1b is acceptable. In this study, it can be seen that the training on green public procurement (X3) has a positive effect/strengthens the relationship between training on green public procurement and the implementation of green public procurement. The results in this study are in line with previous research, which states that training on green public procurement has a positive moderating effect on the relationship between awareness of procurement personnel and implementation of green public procurement [15]. It also verifies that the lack of training on green public procurement is an essential obstacle in implementing green public procurement [3].

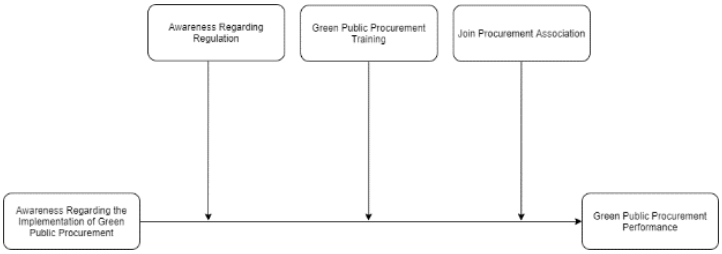

Figure 2: Moderated Regression Analysis Model (MRA)

- H1c: The inclusion of Procurement Personnel in the Procurement Association positively moderates the effect of Procurement Personnel Awareness on the implementation of green public procurement.

The result of SPSS processing, H1c has a significance value of 0.016. In this study, it can be seen that H1c is acceptable. The joining of procurement personnel in the procurement association strengthens the relationship of the procurement personnel in the procurement association to the implementation of green public procurement. The results in this study are in line with previous research, which states that the joining of procurement personnel in procurement associations has a positive moderating effect on the relationship between awareness of procurement personnel and the implementation of green public procurement [15]. This shows that procurement personnel are not only focused on implementing green public procurement but also view associations as a guide in implementing procurement.

5 CONCLUSION

Internal factors of procurement personnel include awareness of procurement personnel regarding the implementation of green public procurement, training on green public procurement, joining procurement personnel in procurement associations, understanding of individuals who encourage the implementation of green public procurement. Data analysis shows that awareness of procurement personnel regarding green implementation public procurement, training on green public procurement, and individual attention significantly influence the performance of green public procurement.

Internal factors of the procurement bureau include support from top management and cross-departmental management that encourage the implementation of green public procurement after data analysis, indicating that upper management support has a significant effect on the performance of green public procurement.

Awareness of procurement personnel regarding green public procurement regulations, training on green public procurement, and the joining of procurement personnel in procurement associations, besides acting as a driving factor, also acts as a moderator in the relationship of awareness of procurement personnel regarding the implementation of green public procurement to the performance of green public procurement. After data analysis, it shows that training on green public procurement and the joining of procurement personnel in procurement associations strengthens the relationship between awareness of procurement personnel regarding the implementation of green public procurement towards the performance of green public procurement.

Many steps can be taken both in the short and long term [27], 1) Bureau/Central Government can improve capacity and quality for education and accreditation of procurement personnel, 2) development of regulations that are consistent and so that they can be applied in the procurement process, 3) The government can also specify the criteria used to determine the need for green public procurement instruments. In addition, it can also be done (4) provide a minimum standard of procurement (in percentage) for each Bureau to encourage procurement personnel to carry out environmentally oriented procurement, and 5) can impose sanctions on Bureaus that do not reach the standards set and provide awards to the Bureau that achieves the standard. Based on the study results, it is also concluded that top management support has a significant effect on the implementation of green public procurement. Things that top management can do are a) intensify information on GPP in strategic meetings, b) present green auditors focusing on environmentally friendly procurement processes, and c) build a special team to carry out sustainable procurement [28].

REFERENCES

[1] Hartomo, G, 2021, ekbis.sindonews.com. Retrieved from Sindo News. https://ekbis.sindonews.com/read/345602/33/anggaran-pengadaan-barang-dan-jasa-capai-rp1214-triliun-di-2021-1614160972.
[2] Meehan, J., and Bryde, D, 2011. Sustainable procurement practice. Business Strategy and the Environment. 20(2), 94–106. https://doi.org/10.1002/bse.678
[3] Bouwer et.al. 2005. Green Public Procurement in Europe 2005 - Status overview. Virage Milieu & Management. 107. http://europa.eu.int/comm/environment/gpp/media.htm#state
[4] Bratt, C., Hallstedt, S. et.al. 2013. Assessment of criteria development for public procurement from a strategic sustainability perspective. Journal of Cleaner Production. 52, 309–316. https://doi.org/10.1016/j.jclepro. 2013.02.007
[5] Rais, S. L. A., et.al. 2018. The Possible Challenges of Green Procurement Implementation. IOP Conference Series: Materials Science and Engineering. 429(1). https://doi.org/10.1088/1757-899X/429/1/012023
[6] Tarantini, M. 2011. A life cycle approach to Green Public Procurement of building materials and elements: A case study on windows. Energy,36(5),2473–2482. https://doi.org/10.1016/j.energy.2011.01.039
[7] Adham, K. N., & Siwar, C. 2012. An empirical investigation of government green procurement (GGP) practices in Malaysia. OIDA International Journal of Sustainable Development. 4(4), 77–87.
[8] Mohamad Bohari, A. A., & Xia, B. 2015. Green procurement framework for the Malaysian construction industry. The 7th International Conference of SuDBE2015, July, 27–29.
[9] Fischer, E. A. 2011. Green procurement: Overview and issues for congress. Environmental Considerations in Federal Procurement. 29–81.
[10] Buniamin, S., *et al.* 2016. Green Government Procurement Practices (GGP) in Malaysian Public Enterprises. Procedia Economics and Finance, 35(16), 27–34. https://doi.org/10.1016/s2212-5671(16)00006-x
[11] Kutner, M.H., et.al. 2004. Applied Linear Regression Models. 4th ed. New York: McGraw-Hill Companies, Inc.

[12] Liana, Lee. 2009. The use of MRA with SPSS to test the effect of moderating variables on the relationship between independent variables and dependent variables. DYNAMIC Information Technology Journal. Volume XIV, No. 2, Pg. 90-97.

[13] Ghozali, Imam. 2013. Aplikasi Analisis Multivariate dengan Program IBM SPSS 21 Update PLS Regresi. Semarang: Badan Penerbit Universitas Diponegoro.

[14] Sugiyono. 2015. Educational Research Methods Quantitative, Qualitative, and R&D Approaches. Bandung: Alphabeta.

[15] Liu, J. 2019. Improving the green public procurement performance of Chinese local governments: From the perspective of officials' knowledge. Journal of Purchasing and Supply Management. 25(3).

[16] Testa, F et.al. 2012. What factors influence the uptake of GPP (green public procurement) practices? New evidence from an Italian survey. Ecological Economics. 82, 88–96. https://doi.org/10.1016/j.ecolecon.2012.07.011

[17] Sönnichsen, S. D., & Clement, J. 2020. Review of green and sustainable public procurement: Towards circular public procurement. Journal of Cleaner Production. 245(October), 118901. https://doi.org/10.1016/j.jclepro.2019.118901

[18] AlNuaimi, B. K. 2019. Public-sector green procurement in the United Arab Emirates: Innovation capability and commitment to change. Journal of Cleaner Production. 233, 482–489. https://doi.org/10.1016/j.jclepro.2019.06.090

[19] Hall *et al.* 2015 Greening the Street-Level Procurer: Challengesin the Strongly Decentralized Swedish System, J Consum Policy. 39:467- 483.

[20] Roman, A. V. 2017. Institutionalizing sustainability: A structural equation model of sustainable procurement in US public agencies. Journal of Cleaner Production. 143 (December 2016), 1048–1059. https://doi.org/10.1016/j.jclepro.2016.12.014

[21] Walker, H., & Brammer, S. 2009. Sustainable procurement in the United Kingdom public sector. Supply Chain Management. 14(2), 128–137. https://doi.org/10.1108/13598540910941993

[22] Aragão, C.G. and Jabbour, C.J.C. 2017, Green training for sustainable procurement? Insights from the Brazilian public sector. Industrial and Commercial Training. Vol. 49 No. 1, pp. 48-54.

[23] Song, H et.al. 2017. Green procurement, stakeholder satisfaction & operational performance. International Journal of Logistics Management. 28(4), 1054–1077. https://doi.org/10.1108/IJLM-12-2015-0234

[24] Björklund, M., & Gustafsson, S. 2015. Toward sustainability with the coordinated freight distribution of municipal goods. Journal of Cleaner Production. 98, 194–204. https://doi.org/10.1016/j.jclepro.2014.10.043 https://doi.org/10.1016/j.pursup.2018.05.002

[25] Sporrong & Brochner 2009. Public Procurement Incentives for Sustainable Design Services: Swedish Experiences, Architectural Engineering and Design Management. Volume 5, Issue 1-2, 24-35.

[26] Ahsan, K., & Rahman, S. 2017. Green public procurement implementation challenges in Australian public healthcare sector. Journal of Cleaner Production, 152, 181–197. doi: 10.1016/j.jclepro.2017.03.055

[27] Tomossy, George and Alam, Shawkat. (2018). Shifting Public Procurement Towards Sustainability: A Comparative Case Study of Indonesia and Australia. Australian Journal of Asian Law. Vol 18 No 2, Article 7: 185-198. https://ssrn.com/abstract=3144889

[28] Puspitasari NB and Glennardo P. 2021. Assessment of green public procurement specifications in government institutions: Case study in Central Java, Indonesia. IOP Conference Series: Earth and Environmental Science. IOP Publishing. 794(1):012093. doi.org/10.1088/1755-1315/794/1/012093

The Development of Procurement Role as a Strategic Function in Public Hospital

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ABSTRACT

Public hospital is non-profit organizations provide health services to the community. One of them is Dr. Kariadi General Hospital (RSDK), the best public hospital in Central Java. Currently, RSDK already have independent procurement unit however, the role of the procurement unit in the business process is still not one that is strategically important. Research's primary goal is to assess the maturity level of procurement organizations to understand the characteristics need to be improved. The research design for data collection is survey research. The analysis method employed is the Supply Management Maturity Model proposed to measure the level of maturity. The measurement of the maturity level of the procurement function is based on 5 characteristics, namely procurement planning, organizational structure of purchasing, organizational processes, human resources and leading, and purchasing control. The results of the study show that maturity level at procurement unit of RSDK is on stage 2 or independent stage. This stage shows that procurement unit has adopts the latest purchasing techniques, but procurement strategy is not aligned with the organization strategy. Characteristics that have poor performance are purchasing control and human resources and leading. The finding of this study provide insight into the importance of increasing the maturity level of the procurement function in supporting the strategic role of procurement.

CCS CONCEPTS

• :; • **Social and professional topics** → Management of organization; Supply chain management; Procurement;

KEYWORDS

Maturity, Public Hospital, Procurement

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1 INTRODUCTION

All organizations require input of goods and services from outside parties. These goods and services can be in the form of goods that are directly related to the main objectives of the organization such as materials, semi-finished goods, and machinery. Additionally, there are items and services that must be obtained from outside sources but are not necessarily related to the organization's primary objectives. Examples include office supplies, cleaning employees, and security personnel. Seeing the magnitude of the need for an organization to procure goods and services, the procurement process is very important for the organization to run.

Getting the appropriate material in the right quantity, from the right source, at the right time, and for the right price is the process of procurement [1]. Procurement is a broad activity, not just buying goods. Procurement activities include determining needs, selecting providers, making negotiations with suppliers, formulating contracts, and purchasing.

Procurement activities greatly affect the position of a company in the company's market. According to [2], a company spends an average 60% of its expanses to pay for material, services, and tools. High expenditure influenced by procurement requires procurement to be managed effectively and efficiently. The better the performance of a procurement unit is doing its job or the more mature the procurement unit, the more likely it is to save on procurement costs [3]. But according to [4] the maturity of procurement in national health services is still relatively low.

Dr. Kariadi Hospital (RSDK) is the best public hospital in Central Java. RSDK already have procurement function operated independently. However, the purchasing department is still developing its strategic position in the business process. According to [4], procurement as the key to achieving enduring competitive advantage at the corporate level is thought to be a strategic function. The hallmark of procurement as a strategic function is that the company's procurement strategy has been fully incorporated with that strategy, and that it is a component of an integrated, cross-functional effort to create a strategic plan [2].

Based on an interview with one of its members of the procurement unit, the role in the business process is not yet a strategic role. The procurement unit is not involved at the procurement planning stage. In addition, in the process of developing hospital facilities, the procurement unit was only involved in the procurement process, not planning.

The procurement department also faced a number of issues. The procurement unit's vision and mission have not yet been properly carried out. While the organization's aims and points of reference are based on its vision and mission. Vision and mission are another method to assess how well an organization is performing its obligations, according to [5]. One indicator of the procurement unit's maturity is its vision and objective [6]. Another problem in the procurement unit is that suppliers are less responsive to their supply and needs. According to [1], measuring the maturity level of the procurement unit can determine whether we need to make changes or not and can determine the plan to make improvements to the procurement unit. A company may select what to improve in its procurement procedures by measuring its maturity level and comparing it to that of other companies [7].

According to [4], procurement is essentials to cost cutting initiatives. In the UK's National Health Service (NHS), procurement is either confronting its biggest financial challenge—inefficiency—or its biggest opportunity. The answers provided are all too frequently packaged as "collaborate more, standardize products, and leverage spend" despite the complexity, diversity, and sheer size of the NHS.

To maintain performance and plan for performance improvement, the procurement unit needs to conduct an assessment. Performance appraisal is important for the organization. Performance appraisal can be used to assess organizational success and can be used as a basis for developing organizational strategies going forward [8[. According [9], the relationship between procurement maturity and performance is favorable. It suggests that the better a procurement unit performs, the more mature it is. In order to assess a procurement unit's performance, its maturity might be measured. To assess the maturity of the procurement function, this study used Supply Management Maturity Model [3]. This method conducts an assessment based on 5 characteristics which are further divided into 19 sub characteristics. There are 4 stages of maturity namely stages 1, 2, 3, and, 4.

This research has two objectives. The first is to determine the level of maturity of the procurement unit. The second objective is to provide recommendations for increasing the maturity level of the procurement unit.

2 LITERATURE REVIEW

2.1 Procurement

All of the management procedures and activities required to make sure that a company can affordably purchase all of the goods and services it needs from outside sources are included in procurement. Many sources describe the definition of procurement. According to [10], the process of locating, accepting conditions from, and acquiring goods or services from suppliers—often through a tendering or negotiation process—is known as procurement. The goals are to ensure buyers get the goods or services at the best price with consideration of quality, quantity, time, and location. In general, procurement is the process of obtaining the right quality for a material, at the right time, with the right quantity, from the right source, and at the right price [1].

Prior to a few years ago, a company did not prioritize buying. In this instance, the procurement task consists just of a discussion of the goods' negotiated price with the supplier and a report on the supplier relationship. Only the cost of acquisition is used to estimate more than 56% of manufacturing costs [11]. Procurement-related expenses accounted for almost 60% of the budget [2]. It demonstrates how strategic procurement is within an organization.

The more competent the procurement function is, as well as its position within the firm, the better it may be determined [12]. A key component of purchasing and supply management is strategic sourcing. 'Satisfying business demands from markets through proactive and planned examination of supply markets and supplier selection with the purpose of delivering solutions to meet established and agreed-upon business needs,' is how it is best described (Baily et al, 2015) [1]. The supplier market analysis process is divided into four stages, namely building commodity profiles, determining price structures, provider research, and identifying key market indicators [13]. Procurement innovation means providing goods or services in an innovative way. Innovation in procurement can be divided into two, namely innovation in the way of procurement which is commonly called procurement innovation or procuring innovative goods which are commonly called innovative procurement [14].

Government procurement is now more significant than ever before in the public sector due to the number of purchases and complexity of the process. Government procurement has been used as a crucial tool for economic development, not just in the technical and management elements [15]. Accordingly, contract management is a crucial task in public procurement, especially for development projects that aim to get the best value for the money [16].

Increased integration in parts will improve procurement and higher company performance. Integration between functions in procurement is the interaction and collaboration of procurement functions with other functions [17]. Lack of integration will reduce the overall competitive level of the company. The procurement unit will focus on reducing costs, while the marketing and research and development departments will focus on product innovation and quality improvement. The misunderstanding above can cause errors in choosing a provider.

Early contractor involvement in public procurement has a number of benefits, but there are still many challenges [18]. Direct contact with specialist contractors, design and build contracts, idea competitions, early contractor sales of ideas to the owner, negotiated bidding procedures, opening for alternative tenders, competitive dialogue, and project partnering are the 12 approaches to early contractor involvement. Indirect approaches, information meetings, front-end partnering processes, project announcements with alternative solutions, design and build contracts, and idea competitions are the other eight.

2.2 Supply Management Maturity Model

A maturity model is a method for determining an entity's level of maturity and the steps that must be taken to advance to a higher level [19]. A procurement unit's maturity level is evaluated using a technique called the procurement maturity model. According to [3], a procurement organization's maturity level and performance are positively correlated, meaning that the more mature an organization is, the better its performance will be in terms of procurement. The Supply Management Maturity Model is one of the maturity models.

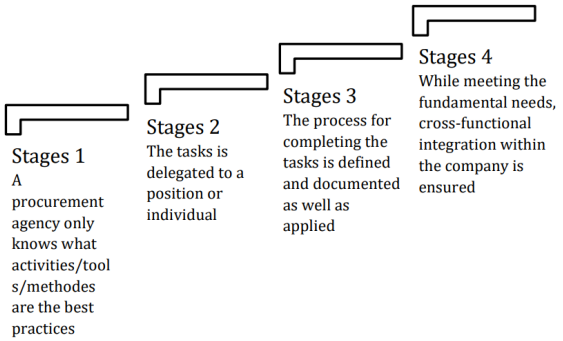

Figure 1: Supply Management Maturity Model

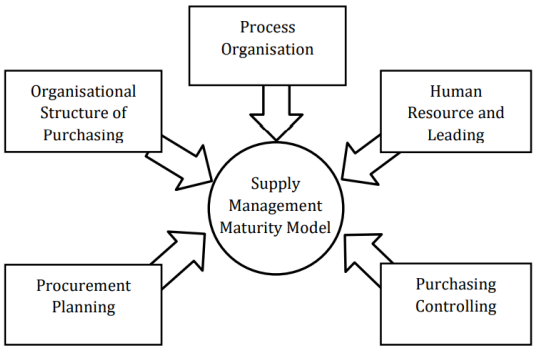

Figure 2: Measurement Indicators

Planning, organization, leadership, and control—the four traditional management function theories—are the factors or characteristics used to gauge a level of maturity [3]. In addition to showing a favorable relationship between maturity and performance, this model also has the advantage of being an empirical study rather than an observation.

The following table shows the results of multiple linear regression:

This model measures the five indicators that affect procurement unit maturity, as shown in the figure 2 below:

An organization's maturity is influenced by five main variables, namely procurement planning, organizational structure of purchasing, organizational processes (Process Organization), human resources and leadership and procurement control. Procurement planning is the first process in conducting procurement such as material specifications, market analysis, and technology identification. The organizational structure is important in assessing the maturity of a procurement service unit, especially in implementing strategies in the organizational structure. Organizational process factors focus on the influence of provider selection strategy and long-term planning. Human resources and leadership are factors that see the professionalism of the agency and members of the procurement. Procurement control is how it is important to measure the maturity of the procurement agency. A good procurement agency must have good control over the hierarchy below it. An organization's maturity is influenced by five factors: procurement strategy, purchasing organizational structure, process organization, human resources and leadership, and purchasing control. Table 2 shows how the five qualities are further broken down into a number of sub-factors [3].

3 METHODOLOGY

This study employs a descriptive methodology and conducts both internal and external research. Internal exploration studies are carried out by searching for and understanding literature from books, journals, and previous research on procurement, procurement maturity, performance appraisal, and government procurement of goods and services. The goal is for researchers to understand more deeply the topics to be discussed and serve as the basis for conducting internal exploration. An internal exploratory study was conducted by interviewing the internal parties of the organization that was the object of the research. The questions asked at the time of the interview were questions obtained from external exploration. Interviews were conducted to find out more about problems that occur in the internal organization.

The research objective was determined based on the formulation of the problem that had previously been formulated. Based on these problems, it is necessary to assess the maturity level of the procurement unit. Procurement maturity or the maturity of the procurement unit is a level obtained by measuring the characteristics of a procurement function. From the measurement results, it can be seen that the characteristics are still lacking and recommendations for improvement can be made to improve the performance of the procurement unit.

This approach comprises four stages and is based on the supply management maturity model [3]. Distribution of questionnaires

Table 1: Supply Management Maturity Model

No	Score	Maturity Stages	Remarks
1	0% – 25%	Stages 1	A procurement agency only knows how activities/tools /methods are the best practice
2	25% – 50%	Stages 2	The task is delegated to a position or individual
3	51% – 75%	Stages 3	The process for completing the task is defined and documented as well as applied
4	76% - 100%	Stages 4	While meeting the fundamental needs, cross-functional integration within the company is ensured

Table 2: Supply Management Maturity Model Characteristics

No	Characteristics	Indicator
1	Procurement Planning (PL)	Plan for Demand (PL1)
		Consolidated Planning (PL2)
		Scan of Environment (PL3)
		Planning for Innovation (PL4)
2	Organizational Structure of Purchasing (OS)	Structure and Purchasing Tasks (OS 1)
		Strategic Integration (OS 2)
3	Process Organization (PO)	Sourcing Strategy (PO 1)
		The Process of Supplier Selection (PO 2)
		Evaluation of Supplier (PO 3)
		Development of Supplier (PO 4)
		Purchasing Early Involvement in Development Process (PO 5)
		Early Supplier Involvement (PO 6)
		Cross Functional Involvement of Purchasing (PO 7)
4	Human Resource and Leadership (HR)	Job Description and Competencies (HR 1)
		Personnel Selection and Integration (HR 2)
		Performance Appraisal and Career Development (HR 3)
5	Purchasing Controlling (CO)	Controlling System (CO 1)
		Controlling Process and Structure (CO 2)
		Controlling Method and Tools (CO 3)

and in-depth interviews regarding the five qualities assessed—procurement planning, organizational structure of purchasing, process organization, human resources and leading, and purchasing control—are the methods utilized to gather data. There are 19 sub components that make up the five characteristics. It is broken down into 56 questions or facets based on the 19 subfactors, and there are 4 answer options for each point, with each option describing a different level. The first response explains level 1 and assigns a value of 0, the second response assigns a value of 1, the third response assigns a value of 2, and the fourth response assigns a value of 3. Based on situations that are similar to the actual conditions at the the procurement unit, respondents will select one response from each evaluation point. The head of the procurement section will be subjected to questionnaires and interviews.

The measurement scale in this study is the ordinal scale. In the process of collecting maturity level data, an ordinal scale is used with a scale of 0, 1, 2, and 3. Each number describes the characteristics of each level in each sub-factor of the Supply Management Maturity Model. The results of data processing will be averaged and made a percentage where the results will describe the level of maturity of the procurement unit.

Calculating the average for each assessment attribute is the first step. The next step is to divide the entire value by the total number of evaluation points to determine the overall average and the maturity level of the procurement organization. The outcomes of the aforementioned calculations are then observed to be at which intervals of development stages. The Supply Management Maturity Model's four levels are used to analyze data and make recommendations by indepth interview and focus group discussion (FGD). The literature was also incorporated to support and further our understanding of these recommendations.

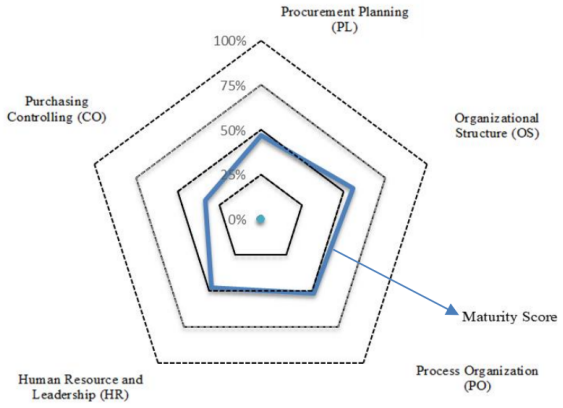

Figure 3: Maturity Score Chart

4 RESULTS

The first stage is to average the value of each characteristic and compare it with Table 1 to determine the maturity level of each characteristic. The calculation results can be seen in Table 3.

The results of data processing above show the maturity of each characteristic. The highest score is procurement organizational structure with a score of 56% and the lowest score is procurement supervision with a score of 33%. There are two characteristics that have reached level 3 and there are three characteristics that are still at level 2. The comparison between the scores of each characteristic and the maturity level scores can be seen in Figure 3.

Table 3: Characteristic Score

No	Characteristics	Indicator	Score			Stages
1	PL	PL1	2.00	67%	47%	2
		PL2	1.33	44%		
		PL3	1.33	44%		
		PL4	1.00	33%		
2	OS	OS1	1.75	58%	56%	3
		OS2	1.50	50%		
3	PO	PO1	2.00	67%	51%	3
		PO2	1.33	44%		
		PO3	1.67	56%		
		PO4	1.67	56%		
		PO5	1.75	58%		
		PO6	1.50	50%		
		PO7	1.17	39%		
4	HR	HR1	1.00	33%	48%	2
		HR2	1.50	50%		
		HR3	1.67	56%		
5	CO	CO1	1.67	56%	33%	2
		CO2	1.00	33%		
		CO3	0.00	0%		

4.1 Procurement Planning

Procurement planning is the first process in conducting procurement such as determining material specifications, market analysis, and technology identification. Demand planning, consolidated planning, environment scan, and innovation planning are the four indicators that make up characteristics of Procurement Planning. 47 percent of respondents gave procurement planning a grade, which shows that stage 2 features are present. There are still numerous areas where these stages can be enhanced.

This score is obtained because there are some aspects that are still poor. In demand planning, the factors considered are only the results of sales and forecasting. In addition, planning is only carried out on certain items. In the aspect of using information technology, procurement unit uses only a simple IT tool, namely spreadsheet, in conducting consolidated procurement planning. In the market observation process, explanation of the market analysis process is still unclear. For resources in conducting market observations, the procurement unit already has members in charge. The role of the procurement unit in the process of identifying technology is to provide information about technology trends to other functions. In addition, technology monitoring is one of the responsibilities of the procurement unit. In the aspect of technology roadmaps, procurement unit knows the roadmaps of products and technology of the suppliers. The roadmaps of important suppliers are also known by the procurement unit. The procurement department also analyzes technology roadmaps. This is one of the obligation of the procurement unit in evaluating supplier into the selection process.

Overall procurement planning is quite good. The value of the characteristic is 47%. The indicator that has the largest value is demand planning with a value of 2.0 and the indicator that has the lowest value is innovation planning with a value of 1.0. The combined planning and market observation value is 1.33. This shows that a critical indicator is innovation planning. So that innovation planning is an indicator that must be improved.

4.2 Organizational Structure of Purchasing

A characteristic of the purchasing department's organizational structure is how the strategy is implemented inside the structure. This characteristic has two indicators, namely structure and mandate, and strategic integration. The scores for each indicator, respectively, are 1.75 and 1.5. This point shows that this indicator is good. The structure and mandate has four aspects. The first is the organizational structure. The organizational structure is an aspect that assesses whether the procurement unit is well established and whether the responsibilities for each member of the procurement unit are clear. This aspect has 2 points. This value is obtained because the procurement unit is well established and is responsible for each procurement activity and the procurement policy is clear. Second is the mandate. The mandate is an aspect of the responsibility of the procurement unit. The mandate aspect of the procurement unit has 1 point. This value is obtained because the procurement unit can initiate programs and measurements in carrying out procurement.

The third is the integration between functions. Integration between functions is an aspect that assesses the interaction between functions and how the response of other functions. In the procurement unit, integration between functions has point 2 because the duties and obligations have been coordinated with all functions based on business processes and are stipulated in a guideline, namely the Director's Regulation. Finally, integration with other procurement units. Integration with other procurement units is an aspect that looks at the relationship between procurement units. This aspect has a point of 2. This value is obtained because the procurement unit is an active part in the network of other institutional

procurement unit groups. There is an exchange of information between the procurement unit and other procurement units, such as with other hospital procurement units in other regional areas.

Strategic integration has a point of 1.5. This figure shows that this indicator is good enough, but can still be improved. This indicator consists of two aspects, namely the meeting of the board of directors and the decision to make and buy. The first is the board of directors meeting and the second is the make or buy decision. The board of directors meeting is an aspect regarding the involvement of the procurement director at the board of directors meeting. This aspect has 1 point. This value is obtained because at the meeting of the board of directors, the director of procurement is always included even though he is not yet part of the executive committee.

Procurement organizational structure has a score of 56%. This characteristic has reached stages 3 meaning that this characteristic is good but can still be improved.

There are some aspects which are still poor on this characteristic. The main task of the procurement unit is to initiate programs and measure of carrying out procurement. At board meetings, the procurement unit represented by the director of procurement, is always included even though it is not yet part of the executive committee.

4.3 Process Organization

The process organization has seven indicators, namely sourcing strategy, supplier selection, supplier evaluation, supplier development, early involvement in development process procurement, early supplier involvement, cross functional involvement of purchasing. Scores of each indicator, respectively, 2.0, 1.33, 1.67, 1.67, 1.75, 1.5, and 1.17. This characteristic has a score of 51%. The score indicates that the organizational process is at stages 3. This means that these characteristics are good.

But there are still some aspects that are not good. Documentation of the supplier selection process at procurement unit has been regulated and defined but is only internally. Contract management is still not explained, only standards have been applied. Communication with suppliers is still poor. Evaluation results are not always communicated with the supplier. Optimization of development is also still poor It's because the Kariadi procurement unit does not make visits to suppliers nor training and workshops with providers. The role of procurement in standardization is to reduce unnecessary complexity in procurement assets, processes and structures. In determining materials / functions, procurement unit contributes by assisting the technical and quality departments in the selection of materials and functions in the development process. Procurement unit assists in the selection of materials and functions through a technical team that is indeed tasked with handling specifications. In early supplier involvement, supplier contributions only provide input at the beginning of the development process. The involvement of marketing, quality, production and logistics, and operative procurement is still not good. Between these sections with procurement only provide information to each other.

4.4 Human Resource and Leadership

Human resources and leading are characteristics that look at the professional aspects and capabilities of a procurement unit. Three factors, including job description and competency, personnel selection and integration, performance evaluation, and career growth, serve as indications for this trait. In order, the points for each indicator are 1.0, 1.5, and 1.67. This characteristic has a score of 48%. A score of 48% indicates that these characteristics are on stages 2. Stages 2 means that these characteristics still need to be improved to become a strategic role.

This value is obtained because there are some aspects that are not good. Aspects of the procurement function has been clearly explained and is an adaptation of the hospital strategy. Technical competence for each technical already has its own SOP according to the type of goods, value of goods, sources of funds and procurement techniques. Integration with other functions currently has training plans, but only for some functions and there are no specific targets. Only when new technologies or changes in how the government purchases products and services are made can training sessions take place. The explanation about the target approval has reached the non managerial level. However, this explanation was only made based on the internal approval of the procurement unit.

4.5 Purchasing Controlling

Purchasing control is a characteristic that looks at how to measure performance and supervision. This characteristic has three indicators, namely controling system, controling process and structure, controling method and tool. The scores of each indicator, respectively, are 1.67, 1.0 and 1.0. Purchasing control has a score of 33%. Based on this score these characteristics are at level 2. A score of 33% indicates that much needs to be improved in the purchasing control process at procurement unit.

This value is obtained because there are still many aspects that are not good enough. Measurement parameters are only implemented in important functions. The controlling organizational structure of the procurement unit already has a planning and controlling function but is not yet well established. In the aspect of responsibility, the procurement unit already has an explanation of the duties and responsibilities but not yet well. The target monitoring process at the Kariadi procurement unit has been applied a comparison between targets and actualization. Correction action needed is done. Measurement of the supervision process at the procurement unit already have a way to determine the results of the supervision process. Commodity coding in procurement unit does not yet have a code for the goods / services being held.

4.6 Maturity Level

Procurement unit currently has a maturity level score of 47.6%. A value of 47.6% indicates that procurement unit on stage 2. Overall the procurement unit is good enough, but there is still much that needs to be improved to reach stage 4 or a strategic role. There are three characteristics that are still in stages 2 and there are two characteristics that are already in stages 3 in procurement unit. The best value is on the organizational structure of purchasing with a value of 56%. This value indicates that the organizational structure of purchasing is on stage 3. The second largest value is the process organization with a value of 51%. Based on these values the characteristics of the process organization are already on stage 3. Stages 3 shows that the procurement function on these

characteristics has supported the hospital's competitive strategy by adopting techniques and best practices. The third biggest value is human resources and leadership with a value of 48%. With a value of 48% of human resources and leadership on stage 2. Procurement planning has a value of 47%. With these values indicate that the characteristics of procurement planning on stage 2. The smallest value is controlling procurement with a value of 33%. This value shows the maturity level of controlling procurement at stage 2. Stages 2 shows that the characteristics at this stage have applied the latest techniques and practices but the strategy is not in line with the hospital strategy.

Based on the measurement of the Maturity Model, it can be seen which aspects are still not optimal, then recommendations for improvement are made by indepth interview to increase the level of maturity of the procurement unit in order to achieve a strategic role. The recommendations are analyze supply markets and product life cycles, consolidated procurement and procurement processes information systems, innovate on procurement, implement contract management practices, improve supplier relationships, improve monitoring and measurement systems, and improve integration with other sections.

Analyze supply markets and product life cycles can assist in making steps to be taken in the procurement process, improve procurement strategies, and help make anticipatory plans if something unexpected happens. Provider research is the process of understanding a provider's structure and history. This stage is the basic stage in conducting provider analysis. At this stage, what can be done is to seek information through internal sources of providers, procurement associations, and annual reports from providers. The final stage is to identify the key market indicators. The provider market analysis process is carried out by building a commodity profile, determining the price structure, researching providers, and identifying key market indicators (Hargraves, 2008).

Consolidated procurement and procurement processes information systems are carried out through the use of information technology for joint planning, an information technology system that can assist the joint planning process should be implemented. The information technology system will be able to be used for related functions as an inventory database and provider.

Innovate on procurement is needed for the procurement process to achieve the unmet needs of the company with innovative solutions [14]. However, what must be considered so that the innovation process does not fail is that there are members who reject the new method, do not understand the potential benefits of innovation and are doubtful about the capabilities and capabilities of members.

Contract management is an important activity in government procurement, especially in development projects while achieving value for money [16]. To achieve value for money, good contract design must also be supported by activities in contract management and assigning experienced staff to supervise consultants and contractors. The procurement unit must ensure that contracts are completed on time, of satisfactory quality, minimized risk, and minimum costs.

Improve supplier relationships need to be done through the involvement of providers in the procurement process. This can improve the performance of the procurement and project. In the process of engagement, an evaluation of the provider is carried out by the procurement unit at the end of the project so as to improve the performance of both parties. The keys to successful provider engagement early in the process are timing of engagement, risk distribution, competence of the project leader, appropriate compensation, qualification of the contract and trust.

Monitoring and measurement systems need to be improved to support organizations to comply with applicable laws, meet accounting and reporting obligations, and achieve strategic objectives, which include protecting resources, misuse, and damage. Supervision of the procurement unit can be done through performance measurement using the Performance Measurement and Management (PMM) method. Meanwhile, the supervision of the procurement process or project can be carried out using the Project Evaluation Review Technique (PERT) and the Critical Path Method (CPM). This method can help users to find out how long the project can take to complete, what the risks are, what critical activities can slow down the project, whether the project is on time, faster, or slower, whether the project should be accelerated, and how to complete the project so that minimum costs are achieved.

Integration with other sections should be enhanced through interaction and collaboration of the procurement function with other functions. Lack of integration will reduce the overall competitive level of the company. The procurement unit will focus on cost reduction, on the other hand, the marketing and research and development departments will focus on product innovation and quality improvement. Misunderstanding above can lead to errors in choosing a provider. Increased integration within the department will lead to higher procurement and company performance [17]. Some other recommendations that need to be done are describing the procurement process to other parts, applying standardization, finding out developments in procurement, training for personil, and detailing targets.

5 CONCLUSION

The conclusions obtained from the research is the general procurement unit of RSDK has carried out its functions well when viewed from the applicable government regulations. However, there are still many activities that have not been formally documented in a technical manual or standard procedure.

Based on the measurement results using the Supply Management Maturity Model, the procurement unit of RSDK is on stage 2. Overall, this stage shows that procurement unit has implemented the latest procurement techniques. But the procurement strategy is not aligned or integrated with the organization strategy. Other characteristics at this level are performance based on efficiency and price reduction. There is a relationship between the procurement unit and the user. Top management at this level is likewise aware of the value of procurement and its ability to increase revenues.

There are 2 (two) characteristics that have reached stage 3, namely the organizational structure of purchasing and process organization. There are 3 (three) characteristics that are at stage 2, namely human resources and leadership, procurement planning, and procurement controlling. The characteristic with the best value is the procurement organizational structure. The characteristic with the smallest value is procurement control.

Recommendations that should be applied to improve procurement maturity is to analyze supply markets and product life cycles, consolidated procurement and procurement processes information systems, innovate on procurement, implement contract management practices, improve supplier relationships, improve monitoring and measurement systems, improve integration with other sections. Other recommendations such as describing the procurement process to other parts, applying standardization, finding out developments in procurement, training for personil between sections, and detailing targets.

REFERENCES

[1] Baily, P., Farmer, D., Crocker, B., Jessop, D., & Jones, D. 2015. Procurement Principle and Management, 11th edition. Pearson Education Limited.

[2] Reck, R.F. and Long, B.G. 1988. Purchasing: a competitive weapon. Journal of purchasing and materials management, 24(3), pp.2-8.

[3] Schiele, H. 2007. Supply-management maturity, cost savings and purchasing absorptive capacity: Testing the procurement–performance link. Journal of purchasing and supply management. 13(4), pp.274-293.

[4] Menzies, L. 2016. Procurement Maturity in Public Healthcare Procurement: An Exploratory Study. 25th IPSERA conference, At Fraunhofer-Institute for Material Flow and Logistics IML.

[5] Keban, Y. T. 2013. Analisis Pengadaan Barang / Jasa Pemerintah Kota Sukabumi, Pemerintah Kota Bogor, dan Lembaga Kebijakan Pengadaan Barang / Jasa Pemerintah (LKPP). Jakarta: Universitas Indonesia.

[6] Guth, R. S. 2010. Best Implementing: Procurement Maturity Model. In 95th ISM Annual International Supply Management Conference.

[7] Tontini, G., Castro, C. Luciano de., Schlindwein, N. F. da Costa , Tomarevski, Victor. 2016. Maturity model of procurement and supply management in small and medium-size enterprises. International Journal of Quality and Service Sciences.

[8] Cahyono, D. 2000. Pengukuran Kinerja Balanced Scorecard untuk organisasi sektor publik. Jurnal Bisnis dan Akuntansi, 2(3), 284-293.

[9] Plomp, M.G. and Batenburg, R.S. 2009. Procurement maturity, alignment and performance: a Dutch hospital case comparison. Proceedings of the 22nd Bled eConference" eEnablement: Facilitating an Open, Effective and Representative eSociety", pp.203-219.

[10] Weele, Arjan. J. 2009. Purchasing & Supply Chain Management: Analysis, Strategy, Planning and Practice. Cengage Learning

[11] Ellram, L. M. 1992. The Role of Purchasing in Cost Savings Analysis. Journal of Supply Chain Management.

[12] Gelderman, V. W. 2005. Purchasing Portofolio Model: A Critique and Update. The Journal of Supply Chain Management: A Global Review of Purchasing and Supply, 19-28.

[13] Hargraves, D. A., & Sourcing, D. S. (2008). Supply market analysis for a competitive advantage. 93rd Annual International Supply Management Conference.

[14] Kautsch, M., Lichoń, M., & Whyles, G. 2015. Tools of innovative public procurement in health care in Poland. Innovation: The European Journal of Social Science Research, 28(3), 312-323.

[15] Thai, V Khi., Grimm, R. 2000. Gonernment procurement: Past and current development. Journal of Public Budgeting, Accounting & Finansial Management, 12,2, pp.231.

[16] Mchopa, A. 2015. Integrating contract management practices into the achievement of value for money in tanzania public procurement: Evidence from selected procuring entities in moshi municipality. Journal of Public Procurement, 15(2), 129-149.

[17] Foerstl, K., Hartmann, E., Wynstra, F., & Moser, R. 2013. Cross-functional integration and functional coordination in purchasing and supply management: Antecedents and effects on purchasing and firm performance. International Journal of Operations & Production Management, 33(6), 689-721.

[18] Wondimu, P. A., Hosseini, A., Lohne, J., & Laedre, O. 2018. Early contractor involvement approaches in public project procurement. Journal of Public Procurement, 18(4), 355-378.

[19] Kohlegger, M., Maier, R., & Thalmann, S. 2009. Understanding maturity models. Results of a structured content analysis (pp. 51-61). na.

Supply Chain Model to Support the Sustainability of Biomass based Power Plants: Indonesia case

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ABSTRACT

New and renewable energy in Indonesia's energy mix in 2025 is 23 percent, including biomass. West Java Province is the largest producer of agricultural rice products in Indonesia, the problem is that the source of the supply of agricultural biomass is spread in various areas. This study aimed to optimize the supply chain model of agricultural biomass for a steam power plant in West Java Province. The variables considered are distance, cost, type of biomass, volume, and seasonal constraints. Energy demand analysis is based on low calorific value data for each biomass by considering supply fluctuations, while supply chain optimization uses a combination of transportation and cost models. The most significant supply of biomass comes from rice husks, followed by palm shells, wood waste, and corn cobs. Sources of supply come from 11 regencies/cities with a radius of 200 km. The boiler capacity for power generation is planned at 25 tons, it requires heat of 456.05 Gcal/day from a minimum of 264.9 tons/day of biomass. There are five intermediary suppliers with supply capabilities between 20 tons - 330 tons, supply chain optimization from intermediate suppliers to the power plant locus results in a mixed biomass unit price of IDR 2088/kg or IDR 775.76 per calorie. To support the sustainable supply of biomass raw materials, in November, December, and January the main sources of supply of biomass are wood waste and palm shells because rice production decreased to only 30%.

CCS CONCEPTS

• **Applied computing**; • **Operations research**; • **Industry and manufacturing**; • **Supply chain management**;

KEYWORDS

Biomass, optimization, power plant, supply chain, sustainability

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1 INTRODUCTION

The use of new and renewable energy is proclaimed by the Indonesian government in the national energy mix of 2025 at a minimum of 23%, of which 2.2% is bio-energy including biomass [1]. Several sources of sufficient biomass available in Indonesia are palm oil waste, sugarcane waste, wood waste, coconut processing waste, rice waste, corn waste, and various other agricultural products [2]. According to IESR [3], the total energy potential that can be produced from 8 types of agro-industrial plants is around 268,610,875 MWh. In a year this energy is equivalent to the energy generated by a power plant (capacity factor 70%) with a capacity of 43,800 MW. This energy potential can replace the use of fuel for High Speed Diesel or Industrial Diesel Oil in the amount of 22,317 kton, a very large amount for oil fuel consumption savings.

The biggest problem with the source of biomass raw materials in Indonesia is its widespread distribution on several main islands and separated by oceans. The collectivity and transportation problems cause the economic value of these biomass sources to increase, thus requiring further development. A number of agricultural industries, in fact, have been designed to be integrated to utilize the biomass fuel of their agricultural waste. Even so, there is still enough agricultural waste that has not been utilized.

Susanto et al [4] have researched a biomass power plant design system made from rice husk using the concept of a small scale biomass power plant with boiler CFB (Circulating Fluidized Bed) technology with a study area in West Nusa Tenggara, and the results are considered feasible. Pratiwi & Asri [5] converted corncob biomass in Gorontalo Province of 412,832 tons, which is 297,537 tons of syngas to fuel power plants. Hanifah et al. [6] conducted a trial using wood pellets and coconut shells as primary energy sources and succeeded in saving boiler fuel costs by 44-45%. Hasibuan et al. studied biomass as renewable energy using pallet-mobile for Food SME's and analysis of feasibility biomass power plant from palm biomass [7-8]. However, these studies have not considered the sustainability and supply chain of the biomass used.

Research on the potential of biomass to fuel power plants was conducted in West Java, considering its position as a center for rice production. The research was conducted to find the maximum potential of biomass resources that can be used as fuel, in the study area with a radius of 200 km from the locus of industrial power plants in the Depok area. The potential study considers procurement costs, including transportation, supply continuity, quality, initial treatment, and other socio-economic aspects related to the utilization of the agricultural waste biomass. Statistically, the biomass potential of agricultural waste in West Java is presented in Figure 1 [9].

No	Districts	Rice Husk (Ton)	Bagasse (Ton)	Corn Cob (Ton)	Palms Shell (Ton)	Coconut Shell (Ton)	Coffee Shell (Ton)
1	Bogor	61,572.2	0.0	115,192.0	3,395.8	331.2	336.4
2	Sukabumi	93,752.9	0.0	4.8	4,308.1	221.8	15.0
3	Cianjur	128,360.9	0.0	4,649.4	891,793.8	528.1	33.0
4	Bandung	68,842.9	0.0	3,418.0	0.0	14.4	608.6
5	Garut	89,879.0	171.7	3,969.5	2,909.0	355.9	252.8
6	Tasikmalaya	88,248.3	0.0	69,199.3	4.1	3.361.7	134.4
7	Kuningan	43,990.7	598.9	2,665.0	0,0	550.0	117.5
8	Majalengka	114,401.2	2,116.7	48.2	0,0	93.5	19.6
9	Sumedang	60,533.8	42.1	14,215.7	0,0	273.9	76.3
10	Indramayu	275,285.9	1,244.6	8,343.2	0,0	372.9	0.0
11	Subang	188,586.4	4,062.9	73.1	1,111.6	301.2	44.2
12	Purwakarta	28,764.0	0.0	62.0	0.0	110.6	17.2
13	Karawang	223,562.8	0.0	542.4	0.0	150.8	18.6
14	Bekasi	109,928.0	0.0	14.2	0.0	70.4	0.0
15	Bandung Barat	31,797.7	0.0	2.2	36.7	148.0	110.0
16	Bogor City	60.9	0.0	25.1	0.0	0.0	0.0
17	Sukabumi City	3,020.7	0.0	12.4	0.0	0,1	0.0
18	Bandung City	1,463.4	0.0	21.5	0.0	0.0	0.0
19	Bekasi City	609.0	0.0	0.2	0.0	0.0	0.0
20	Depok City	93.0	0.0	12.7	0.0	0.0	0.0
21	Cimahi City	81.3	0.0	0.0	0.0	0.0	0.0
22	Tasik City	7,408.3	0.0	0.0	0.0	82.7	0.5
	WEST JAVA	1,816,991.4	15,017.4	230,371.2	12,657.1	11,136.0	1,877.6

Figure 1: Biomass potential in West Java is calculated from the conversion of the proportion of agricultural raw materials [9]

Theoretically, rice husks are 20% of the mass of paddy; corn cobs 12% of the mass of corn; bagasse 34% of the mass of sugarcane; coconut shell 12% of the mass of coconut; palm shells 6% of the mass of fresh fruit bunches; and coffee shell 9% of the mass of coffee cherries [10-14].

Wood waste that can be used as biomass is the result of industrial processes. Statistically, the West Java Provincial Forestry Service publishes reports on logs, sawn timber, and plywood. Wood waste throughout 2020 that can be utilized in the province of West Java is calculated to be around 457,324.5 m3 [15].

2 METHODOLOGY

2.1 Calculation of Basic Energy Needs

As the basis for the calculation, the amount of energy needed to be used for steam generators is used [16-18]. Boilers used in medium and large scale manufacturing industries, an average of 25 Tons per hour as shown in Figure 2.

2.2 Supply Chain Analysis

The basic concept in supply chain analysis is to use intermediary suppliers to collect biomass from the main suppliers. These intermediate suppliers cover costs for the purchase, handling, transportation and temporary storage of the biomass. Thus, the intermediary supplier will charge this fee on the selling price.

In the proposed concept, it should be noted that large industries, such as the sugar industry, wood pellets, and the wood industry, act directly as intermediary suppliers. The biomass supply chain for this fuel project is diagrammatically presented in Figure 3 [15].

2.3 Biomass Supply Chain Optimization

Each area is calculated on the basis of its average biomass price by considering the supply of biomass using the following formula [19]:

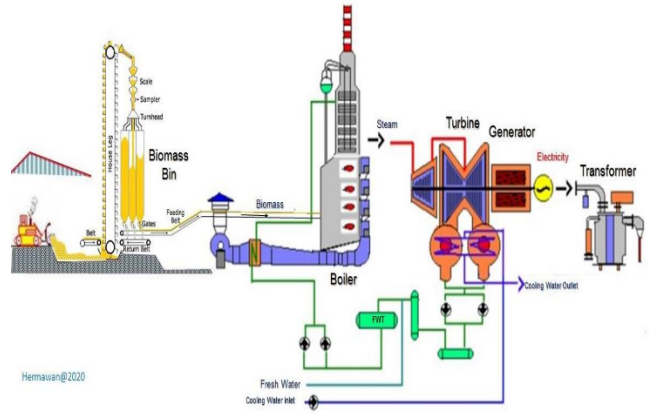

Figure 2: The use of biomass as boiler fuel for power generation in industry [16-18]

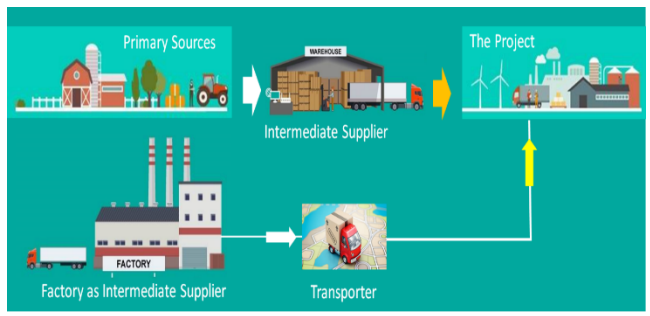

Figure 3: Biomass supply chain model for steam power plant.

$$\text{Cdistrictbiomass} = \left(\sum_{i=1}^{n}(Vi\ x\ Ci)\right) / \text{Cdistrict biomass} = \left(\sum_{i=1}^{n}(Vi\ x\ Ci)\right) / \sum_{i=1}^{n} Vi \quad (1)$$

where:

V is the type of biomass available (1, . . ., n)

C individual base price of biomass (1, . . ., n)

The calculation in (1) is only used to estimate the economic value of the biomass price at the Intermediate Supplier level.

The collection of biomass from primary suppliers in each area to intermediate suppliers is modeled using the transportation method with the following formula:

ai = the number of district sources, where i = 11 from districts/ cities of primary suppliers

bj = number of intermediate suppliers where j = 5

dij = is the distance between the source to the distribution zone then minimized:

$$Z = Z = \sum_{j=1}^{11}\sum_{i=1}^{5} X_{ij} d_{ij} \quad (2)$$

Table 1: Estimated distance of biomass source to steam power plant locus in Depok

Biomass Source Location	Volume (Ton)	Distance to Depok (Km)	Remark
Karang Sinom-Indramayu	330.00	186.4	Close to Subang
Subang	74.85	142.1	
Purwakarta	4.00	110.1	
Kerawang	21.00	89.0	
Bekasi	25.50	42.0	
Cianjur	24.20	95.6	
Bogor	18.00	44.1	
Sukabumi	18,80	99.9	
Lebak – Banten	60.00	129.9	Close to Bogor
Serang – Banten	52.20	102.0	
Pandeglang - Banten	5.50	119.2	

Basic Requirement		264,9 Ton/day				
Base on Depok energy project						
		Potential Biomass Supply				
Periods	Wood wastes (Ton)	Ricehusk (Ton)	Corncob (Ton)	Palms Shell (Ton)	**Total (Ton)**	**Requirement** (Ton)
Jan	512	11.941		1.500	13.953	7.947
Feb	512	16.704	300	1.500	19.016	7.947
Mar	512	16.704	300	1.500	19.016	7.947
Apr	512	16.704	300	1.500	19.016	7.947
May	512	358.236		1.500	360.248	7.947
Jun	512	358.236	300	1.500	360.548	7.947
Jul	512	501.120	300	1.500	503.432	7.947
Aug	512	501.120	300	1.500	503.432	7.947
Sep	512	501.120		1.500	503.132	7.947
Oct	512	501.120	300	1.500	503.432	7.947
Nov	512	11.941	300	1.500	14.253	7.947
Dec	512	11.941		1.500	13.953	7.947
YEAR	6.138	2.806.888	2.400	18.000	2.833.426	**95.364**

Figure 4: Biomass requirement for steam power plant [15]

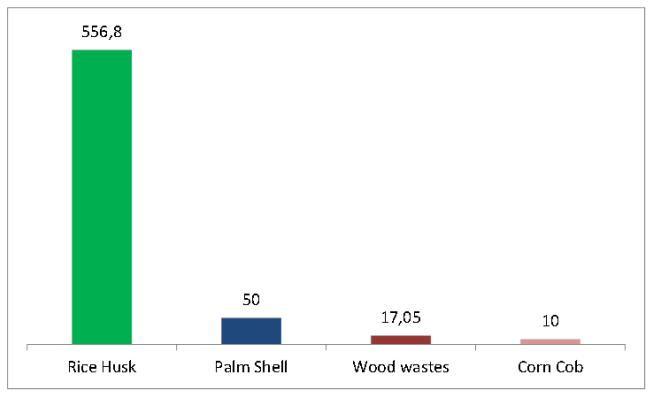

Figure 5: Biomass that can be supplied by primary suppliers (Ton/day) [15]

Under the condition

$$\sum_{j=1}^{11} \leq a_i \tag{3}$$

$$\sum_{i=1}^{115} \geq b_i \tag{4}$$

$$X_{ij}\ 0 \tag{5}$$

The simply optimizations are solved with the Vogel algorithm. The matrix resulting from the optimization of biomass distribution is then multiplied by the cost of biomass which consists of the purchase price per area or Cdistrict biomass, the price of transportation Ctransportation , and the cost of handling Chandling.

3 RESULT AND DISCUSSION

3.1 Calculation of Fuels Requirement

The establishment of a new power plant is planned in the Depok area, West Java. The biomass feedstock is designed for steam power plants with a boiler capacity of 25 tons/hour. With a boiler efficiency of 75-80%, the overall biomass requirement for the project is 95,365 tons per year. Research by Sihombing et al. [20] used 75% efficiency in boilers fueled by fibre and palm oil shell biomass. Throughout the year, this biomass can be filled with natural biomass, even though the rice harvest period decreases in January, November and December [21]. The shortage of paddy in November, December, and January can be covered by utilizing wood waste and palm oil shells. Figure 4 presents the results of calculation of biomass raw materials for the planned establishment of a steam power plant at the Depok locus.

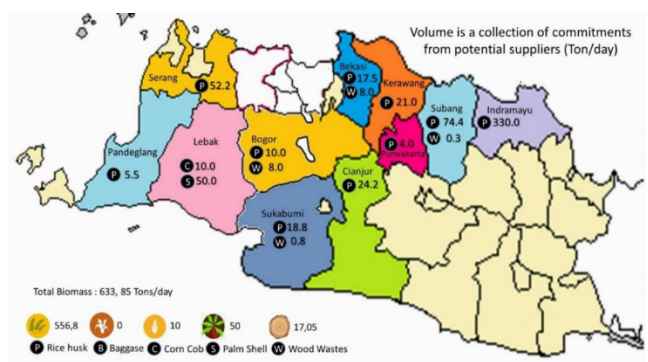

Figure 6: Distribution biomass potential to supply steam power plant locus in Depok

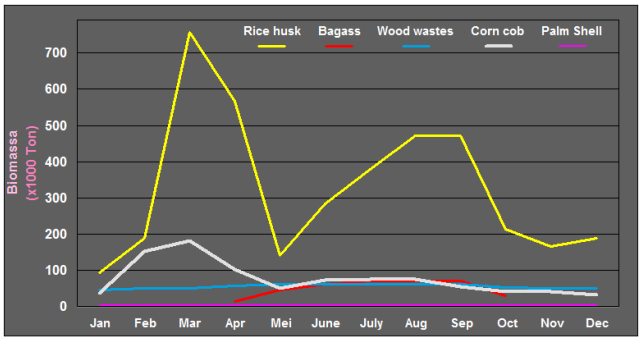

Figure 7: Annual biomass availability following harvest pattern in Java (processed from several references)

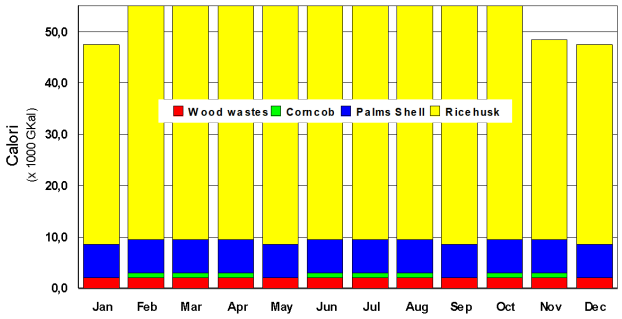

Figure 8: The pattern of biomass calorie supply for steam power plant locus in Depok

3.2 Nearest Supply to Power Plant Locus

The survey was conducted in almost all regencies/cities in West Java, Banten, and Jakarta so that the potential volume of biomass collected from 142 potential suppliers reached 701.85 tons/day. However, after checking the distance between each prospective supplier to Lokus Depok, 83 potential suppliers were selected with a total volume of 633.85 tons/day as shown in Figure 5.

In general, the distribution of biomass in West Java, Banten and Jakarta is presented in Figure 6. Estimated distances from biomass sources are summarized in Table 1 [15].

3.3 Supply Continuity

The harvest pattern of biomass-producing commodities in Java from year to year follows a certain pattern, so it is not available throughout the year. Paddy will experience peak harvest in March-April and August-September. Corn in February and March. The sugarcane harvest reaches its peak in July-September. According to Hermawan [22], the harvest pattern is strongly influenced by the pattern of weather changes in Indonesia. So entering the rainy season, November-January, maybe only wood can be relied on.

Oil palm shells can be an alternative source of biomass in Java, although the plantation centers are only in a small part of Garut, Tasikmalaya and Subang districts. However, in Banten Province, which is about 200 km from the Depok power plant locus, oil palm plantations and processing are quite intensive. West Java and Banten can be sources of supply of palm shells. Figure 7 shows the pattern of biomass availability in Java by harvest pattern [23].

The availability of biomass for industrial locus in Depok, West Java throughout the year, using the Low Caloric Value (LCV) conversion factor of each biomass, is shown in Figure 8.

3.4 Strategy for Sustainable Supply of Biomass Feedstocks

Biomass sources from all identified districts/cities are analyzed for collection pathways to identified intermediary suppliers. Intermediate suppliers collect biomass from primary suppliers spread across West Java, Banten, and DKI Jakarta. For the steam power plant at Depok locus, at least five intermediate suppliers have been identified, namely: Supplier-1 Karang Sinom; Supplier-2 Cileungsi; Supplier-3 Cidahu; Supplier-4 Cipanas; and Supplier-5 Bekasi. Figure 9 shows

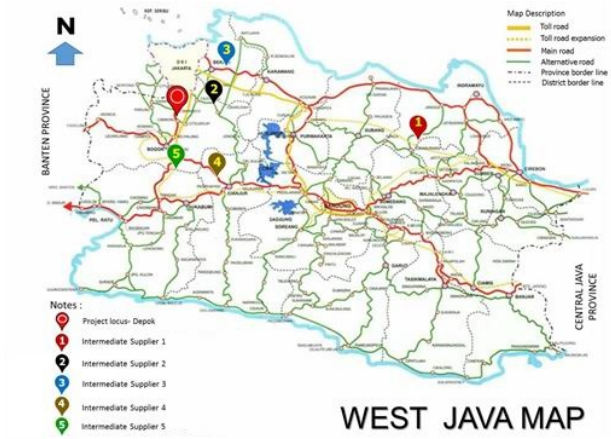

Figure 9: Biomass distribution path from intermediate suppliers to power plant locus in Depok

the biomass supply lines at locus Depok from five intermediary suppliers.

3.5 Optimization of Distribution

Distribution of sources of biomass supply with a distance of 200 km from Depok locus, spread over 11 districts in West Java and Banten. Sending to intermediary suppliers should keep costs to a minimum. Optimization of transportation costs from primary sources to intermediary suppliers is carried out using the Vogel's algorithm [19], which takes into account road distances and supply volumes. The use of the Vogel algorithm succeeded in finding the optimal conditions in #2 iteration with a distribution pattern as shown in Table 2.

The components of the cost of procuring biomass from primary sources to intermediary suppliers consist of: 1) transportation costs (distance costs and vehicle rental); 2) handling costs (packaging and handling costs); and 3) the price of the biomass itself. The cost of procuring biomass which consists of transportation and material handling costs [7]. The overall cost of procuring biomass at the intermediate supplier level is calculated as seen in Table 3.

Table 2: Results of optimization of biomass distribution from primary sources to intermediate suppliers daily

Primary Sources	Intermediate Supplier				
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Serang		52.2			
Pandeglang		5.5			
Lebak		58.8	1.15	0.05	
Sukabumi				18.8	
Cianjur			24.2		
Bogor		18			
Bekasi		5.5	0		20
Kerawang		21			
Purwakarta		4			
Subang			74.65		
Indramayu	330				0
Total Collect	330	165	100	20	20

Table 3: Overall cost of procuring biomass for intermediary suppliers in West Java (IDR/day)

Descrip-tion	Intermediate Supplier				
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Procure-ment costs (IDR/kg)	137,480,000	187,893,592	111,239,758	13,260,023	6,536,506
Cost (IDR/kg)	416.61	1,138.75	1,112.40	663.00	326.83
Intermedi-ate supplier fees (IDR/kg)	5019.19	1,391.80	1,359.60	810.33	399.45
Economic price of intermediate supplier (IDR/kg)	926	2,531	2,472	1,473	726

Table 4: Calculation of the average economic price of biomass for steam power plant in Depok locus

Description	Intermediate Supplier				
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Intermediate Price (IDR/kg)	926	2,531	2,472	1,473	726
Capacity (ton)	330	165	100	20	20
Distance to Depok (km)	183.8	28.2	52.4	74.1	68.3
Number of Trucks @ 4 Ton (unit)	83	41	25	5	5
Far Cost (IDRx1000)	3,125	479	891	1,260	1,161
Transportation Costs (IDRx1000)	257,780	19,775	22,270	6,299	5,806
Biomass Cost (IDRx1000)	305,511	417,541	247,199	29,467	14,526
Cost in Factory (IDRx1000)	563,291	437,317	269,469	35,765	20,331
Biomass Cost (IDR/kg)	1,707	2,650	2,695	1,788	1,017

Taking into account operating costs (10%), overhead costs (10%), and supplier profits between (15%), it is estimated that the average economic price of biomass in the Depok locus plant is shown in Table 4. To calculate the cost of money due to advance payments by the intermediary supplier to the main supplier, the 35% margin is intentionally calculated against the project selling price.

Thus the price of mixed biomass up to the location of the steam power plant locus in Depok can reach IDR 775,76 per calorie, still

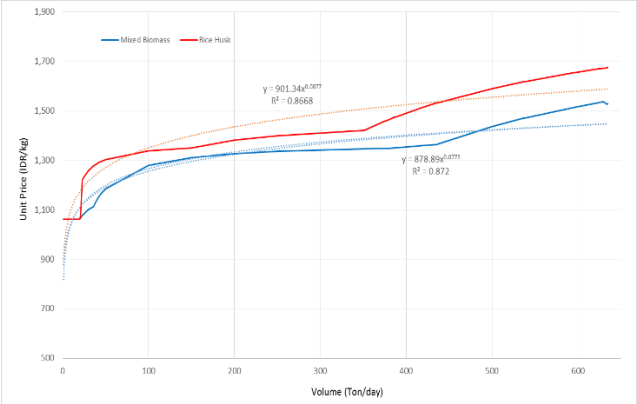

Figure 10: The movement flow of biomass prices following the rate of consumption in West Java

cheaper than coal with the price at the Depok factory door IDR 1.071,43 per calorie. According to [24-25] the use of oil palm shells can save 47,94% than the use of coal, while in this research using mixed biomass the savings are only 27,60% [26].

For the case of prices in West Java, a graph of the relationship between the price of biomass and the growth of biomass volume can be made. If the required biomass is still small, then the price is relatively cheap [26-27]. However for a project scale that requires more biomass, the price will increase significantly. The graph of the relationship between price and biomass volume in West Java is shown in Figure 10.

4 CONCLUSION

Taking into account the sustainability of the supply of biomass feedstocks, the Depok locus is considered appropriate for the construction of a steam power plant. To support the boiler with a capacity of 25 tons, a supply of 95,364 tons of biomass per year or around 264.9 tons per day is needed, consisting of rice husks, corn cobs, wood waste, and palm shells. Biomass potential is 633.85 tons/day from 11 districts/cities in a radius of 200 km involving 83 primary suppliers.

In the proposed biomass supply chain model, the power plant does not directly source biomass feedstock from primary suppliers, but from intermediate suppliers. The intermediate supplier collecting biomass from five primary suppliers and committing to supply to power plants with supply capabilities varying from 20 tonnes/day to 330 tonnes/day.

Optimization using the Vogel transportation model from all regencies/cities to the power plant locus, resulted in the estimated biomass price varying among intermediate suppliers, in the range of IDR 1,017 – IDR 2,695 per kg of mixed biomass. Thus, the average price of mixed biomass for power plants in Depok site is IDR 2,088/kg or IDR 775.76/calorie.

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REFERENCES

[1] Global Affair Canada. 2019. Peningkatan Peran Energi Terbarukan di Sektor Ketenagalistrikan Indonesia. Laporan Proyek Canada–Indonesia Trade and Private Sector Assistance (TPSA), Jakarta.
[2] Japan Institute of Energy. 2008. Panduan Produksi dan Pemanfaatan Biomassa. Laporan Kerjasama Asia dengan Kementerian Pertanian, Perikanan, dan Kehutanan - Jepang.
[3] IESR. 2019. Laporan Status Energi Bersih Indonesia. Institute for Essential Services Reform (IESR), Jakarta
[4] Susanro, R., I. Vanany, dan C. Utomo. 2014. Studi Kelayakan Finansial Dengan Mempertimbangkan Kelangsungan Bahan Baku Khususnya Sekam Padi pada Pengembangan Proyek Biomass Power Plant: Studi Kasus di Lombok-NTB. Prosiding Seminar Nasional Manajemen Teknologi XXI, Program Studi MMT-ITS, Surabaya 19 Juli 2014, pp. 1-12.
[5] Pratiwi, A.I. dan M. Asri. 2018. Analisis Pembangkit Listrik Tenaga Biomassa Berbasis Tongkol Jagung. *Jurnal Dielektrika, Vol.* 5, No. 2, pp. 108-115.
[6] Hanifah, U., N.D. Susanti, dan M. Andrianto. 2019. Kinerja Mini Boiler Tipe Pipa Api 3 Berbahan Bakar Biomassa Pelet Kayu dan Tempurung Kelapa. *Jurnal Agritech,* Vol. 39, No. 3, pp. 200-206.
[7] Hasibuan, S., Adiyatna, H., and Hidayati, J. 2021. Financial analysis of raw material supply chain for power plant using renewable palm biomass. *IOP Conf. Ser.: Mater. Sci. Eng.*, Vol. 1122, 3rd TALENTA Conference on Engineering Science and Technology 28th September 2020, Medan, Indonesia, pp. 1-8. DOI: 10.1088/1757-899X/1122/1/012087
[8] Hasibuan, S., Adiyatna, H., Widowati, I., and Kandasamy, J. 2010. Feasibility Analysis of Compact-Mobile Biomass Pallet Technology as Renewable Fuel for Small and Medium Industries. *International Journal on Advance Science, Engineering and Information Technology*, Vol. 10, No. 6, pp. 2484-2490. DOI:10.18517/ijaseit.10.6.13775
[9] Central Statistical Bureu, 2020. East Java in Figure. Balai Pustaka, Jakarta.
[10] Haluti, S. 2014. Pemetaan Potensi Limbah Tongkol Jagung Sebagai Energi Alternatif di Wilayah Provinsi Gorontalo. Tesis. Institut Teknologi Sepuluh Nopember. Surabaya. https://repository.its.ac.id/48728/1/2412201005-Master-Thesis.pdf
[11] Ardiani, N. 2009. Rantai Pasokan Jagung di Daerah Sentra Produksi Indonesia. Pangan Edisi No. 53/XVIII/Januari-Maret 2009.
[12] FAO. 2012. FAO/INFOODS Density Database Version 2.0. FAO https://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/
[13] Nainggolan, S.R., Tamrin, Warji, dan B. Lanya. 2013. Performance Test of Lab Scale Batch for Rough Rice Drying using Husk of Rice Fuel. *Jurnal Teknik Pertanian Lampung, Vol* 2, No. 3, pp. 161-172.
[14] Hendaryati, H. 2012. Analisis Efisiensi Thermal pada Ketel Uap Pabrik Gula Kebonagung Malang. *J. GAMMA*, Vol. 8, No. 1, pp. 148 - 153
[15] Hasibuan, S., Hermawan, T., and Jaqin, C. 2021. Rantai Pasok Energy Biomassa di Indonesia: Studi Kasus Jawa Barat dan Jawa Timur. Jakarta: Sumalaba.
[16] Hasibuan, H.C. dan F.H. Napitupulu. 2013. Analisa Pemakaian Bahan Bakar Dengan Melakukan Pengujian Nilai Kalor Terhadap Perfomansi Ketel Uap Tipe Pipa Air Dengan Kapasitas Uap 60 Ton/Jam. *Jurnal E dinamis*, Vol. 4, No. 4. pp. 239-243.
[17] Ginanjar, T., Junaidi, G.S. Lubis., dan Y.M. Simanjuntak. 2020. Analisa Kebutuhan Bahan Bakar Boiler dengan Melakukan Uji Kalori pada Pabrik Kelapa Sawit PT. Sentosa Prima Agro. *Jurnal Fakultas Teknik Universitas Tanjung Pura, Vol. 6, No. 2.*
[18] Laila, L dan Y. Qoderi. 2019. Analisis Kebutuhan Energi Pabrik Kelapa Sawit Sungai Rungau Mill. *Journal of Applied Science*, Vol. 1, No. 1, pp. 42-49.
[19] Operations Research
[20] Sihombing, V., N. Haryanto, dan S. Saodah. 2014. Analisis Perhitungan Ekonomi dan Potensi Penghematan Energi Listik pada Pembangkit Listrik Tenaga Uap di Pabrik Kelapa Sawit PT. X. *Jurnal Reka Elkonomika Itenas*, Vol. 2, No. 2, pp. 90-102.
[21] Zamzami, A. 2019. Musim Tanam Padi Sawah 2020. Publikasi Simluhtan-Kementerian Pertanian, Jakarta. http://cybex.pertanian.go.id/mobile/artikel/89424/MUSIM-TANAM-PADI-SAWAH-2020/
[22] Hermawan, E. 2010. Pengelompokan Pola Curah Hujan Yang Terjadi di Beberapa Kawasan P. Sumatera Berbasis Hasil Analisis Teknik Spektral. *Jurnal Meteorologi dan Geofisika,* Vol. 11 No. 2, pp. 75-85
[23] Aldrian, E, and R.D., Susanto. 2003, Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature, *Int. J. Climatol*, Vol. 23, No. 12, p. 1435-1452. https://doi.org/10.1002/joc.950
[24] Akhidiyatul, E. Radwitya, dan Y. Chandra. 2018. Analisis Teknis dan Ekonomis dalam Penggunaan Bahan Bakar Biomassa di Pusat Listrik Tenaga Uap Studi Kasus di PLTU PT Suka Jaya Makmur. *Jurnal ELKHA*, Vol. 10, No. 2, pp. 49-55.

[25] Wibowo, A. 2016. Perancangan Sistem Pembangkit Listrik Biomassa Sawit (PLTBS) Kapasitas 5 MW. *Jurnal Mekanika dan Sistema Termal* JMST, Vol. 1, No. 2, pp. 53-60.

[26] Faisal, M. 2017. Utilization Biomass and Coal Mixture to Produce Alternative Solid Fuel for Reducing Emission of Green House Gas. *International Journal on Advanced Science Engineering and Information Technology*, Vol. 7, No. 3, pp. 950-956.

[27] Kevin, V. 2018. Biomass Energy System for F&B Industry Case Studies in an Indonesian Prespective. *Food Review Indonesi*a

Application of Life Cycle Assessment to Determine Hotspots for Environmental Impacts of The Rayon Production Process: Indonesia Case

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ABSTRACT

In accordance with SDG targets No. 7, 9, and 12 for efficient use of resources and adopting clean and environmentally friendly technology and efficiency in energy use in industrial processes. It is necessary to determine the environmental impact, especially in the Indonesian rayon industry quantitatively using a life cycle assessment (LCA). In Indonesia, according to the Minister of Environment and Forestry Regulation No. 21 of 2021, LCA calculations need to be carried out to obtain a Green and Gold PROPER performance rating. The purpose of this research is to determine environmental improvement hotspots resulting from LCA calculations using SimaPro 9.2.0.2 software. The most significant contribution (hotspots) from rayon production is the use of bituminous coal at the mine or 1E+09 MJ of coal is used in the coal combustion process in the boiler which is used as electrical energy and steam. Determination of alternative hotspots for improvement from the results of the following environmental impacts to create new renewable energy (NRE) or co-firing in the combustion process in the boiler, there are several alternatives such as biomass or the manufacture of solar panels for alternative energy used in the production process.

CCS CONCEPTS

• **Applied computing**; • **Operations research**; • **Decision analysis**;

KEYWORDS

Life Cycle Assessment, environmental impacts, rayon industry

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1 INTRODUCTION

The rayon industry is a supporter of the existence and sustainability of the textile sector in Indonesia. According to Indonesia's Ministry of Industry, the growth rate of the textile product textile industry is one of the strategic sectors that has been hardest hit by Covid-19. This industry recorded a contraction of 4.54 percent in the second quarter of 2021 on an annual basis. But every quarter began to grow 0.48 percent. Exports during the first semester of 2021 also grew 13 percent and investment rose 27 percent. The Indonesia government has taken a number of steps to minimize the impact of Covid-19 on the textile industry and textile products in the country. One of them is by developing the textile raw material industry from the domestic industry. This development is pursued by increasing the capacity of the rayon industry from 856,700 tons at present to 1.21 million tons in 2023 and its dissolving pulp capacity to 1.31 million tons. In addition, increasing the utilization of the polyester fiber and filament industry to 70% by 2023 is also one of the targets [1]

Climate change and inequality affect every country across the continent and are ready impacting national economies and affecting lives. Sustainable development is a need and priority for all people around the world. It is defined as the development of today's world with a view to future generations. In 2015, United Nations Member States established the 2030 Agenda, including seventeen "Sustainable Development Goals" (SDGs) which must be realized by 2030. The targets cover all areas of life, namely the quality of human life, ecosystems, world peace, or partnerships. Each goal has an environmental context [2].

To support the SDGs which contain 17 targets, some of the targets include No. 7, 9, and 12 [3]. In accordance with SDGs targets No. 7,9 and 12 for efficient use of resources and adopting clean and environmentally friendly technology and efficiency of energy use in industrial processes, it is necessary to calculate the environmental impact [4]. Especially in the rayon industry quantitatively, namely by means of a life cycle assessment (LCA) to determine the magnitude of the environmental impact in producing a product. According to the "United Nations Environment Program" (UNEP), the LCA method is the perfect method in the context of the environmental dimension of the SDGs. This concept does not only concern the effects of the production process/system or product/service but also all stages of life (cradle to grave), taking into account the carbon footprint, environment, consumers, or biodiversity. LCA is the only comprehensive eco-innovation indicator and sustainable development policy implementation technique in enterprises in terms of eco-efficiency and eco-products. This mini-review provides a survey

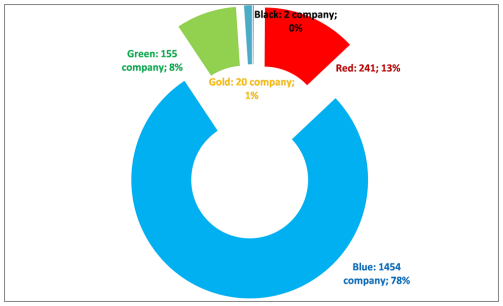

Figure 1: Achievement PROPER

of current knowledge on sustainability and sustainable development and the relevance of new holistic methodologies bridging SDG's with LCA, based on the latest scientific literature worldwide [2].

To support a clean production process and reduce environmental pollution, the Ministry of Environment launched the Company Performance Rating Program in Environmental Management (PROPER) in accordance with the Minister of Environment Regulation No. 3 of 2014 [5] which has now changed to the Regulation of the Minister of Environment and Forestry No. 21 of 2021 concerning the PROPER. In PROPER there are several categories of assessment criteria as awards for the success of environmental management, i.e. Gold, Green, Blue, Red, and Black [6].

PROPER itself is very effective in reducing environmental pollution and reducing sources of GHG (Greenhouse Gas) emissions in various industries in Indonesia. Current accordance PROPER participation in the rayon industry itself in Indonesia, only 1 company out of 4 companies, namely PT. South Pacific Viscose from 2016 - 2020 with a Blue PROPER rating. While for 3 rayon companies in Indonesia, namely PT. Indo Bharat Rayon, PT. Asia Pacific Rayon and PT. Rayon Utama Makmur of the 3 companies, PT. Indo Bharat Rayon did not participate in PROPER due to environmental cases in 2016, for PT. Asia Pacific Rayon did not participate in PROPER because it was still a new company, inaugurated in 2020, and for PT. Main Rayon Makmur did not participate in PROPER due to environmental causes and was temporarily closed in 2018 for repairs [7]

In 2019 the PROPER category was dominated by Blue (77.7%), followed by Red (12.9%), Green (8.3%), Gold (1.1%), and Black (0.1%). The Blue rating category is still classified as meeting the quality standards set by the Indonesian government, while the Red and Black categories are considered disobedient because they are still unable to meet environmental quality standards. Only a few companies whose environmental performance is in the Green and Gold category with performance exceeding environmental quality standards and have made efforts to improve the environment continuously. To obtain the results of the Green assessment, one of the requirements that must be met is the existence of a LCA to evaluate the process life cycle of a product. LCA is one of several environmental management techniques (e.g. risk assessment, environmental performance evaluation, environmental audit, and environmental impact assessment) and may not be the most appropriate technique to use in all situations. LCA is usually do not address the economic or social aspects of a product, but the life cycle approach and methodologies described in this International Standard can be applied to other aspects [8]. The advantage of getting a Green category performance rating for companies is to improve the company's image in environmental management, eco-labelling of environmentally friendly products so that it has implications for increasing product sales both domestically, especially in the global market and supporting the acceleration of achieving SDG's by 2030.

Several industries have adopted the LCA method in identifying their environmental impacts, including the aquaculture industry in China with the object of research analyzing the environmental impacts of pufferfish cultivation from the seed rearing stage, deep-sea cage cultivation, circulation of the aquaculture industry deep-sea cage cultivation by using the GaBi 10.5 software, the CML-IA method [9]. In Indonesia, which has adopted LCA, one of which is Canned Crab (BSC) products, which are exported, especially in cans. LCA evaluates production in 1 ton of BSC cans on the market as a functional unit (FU) with a cradle-to-market system limitation. At the processing stage, the highest contributor (hotspot) was found as an impact category that was considered, especially the use of tin cans for packaging [10].

From several industries that have calculated the environmental impact quantitatively using the LCA method, it can be seen that in producing a product the environmental impact can be calculated and the rayon industry it self has not performed quantitative calculations using the LCA method to determine the environmental impact of producing a product. In accordance with the SDGs 2030 target for SDGs that prioritizes environmental aspects and according to the Regulation of the Minister of Environment and Forestry No. 21 of 2021 concerning the PROPER Program, it is necessary to carry out a life cycle assessment in the rayon industry to find out hotspots for environmental impacts quantitatively and make environmental improvements according to the results of the analysis. Environmental impact quantitatively using the LCA method.

Life Cycle Assessment is a methodology for evaluating the environmental impact of a product by measuring all related inputs and outputs, such as materials, energy, waste and emissions. The product life cycle requires taking into account all production processes, from raw material extraction to waste disposal, considering a "gate to gate", "cradle to gate" or a "cradle to grave" perspective" [11, 12]. LCA is usually adopted to evaluate the carbon footprint and water footprint of packaged foods considering the entire supply chain, but not many studies compare the results derived from the adoption of different Life Cycle Impact Assessment methodologies [13].

2 METHODOLOGY

2.1 Research Type

The type of this research is quantitative research. In this research the data used are:

- Primary data, this data obtained from within the company both when conducting interviews with related parties and external.
- Secondary data, the secondary data used in this study were obtained obtained from observation in the field, including direct observation of the production process from raw materials being processed into finished rayon products and seeing

the process of burning coal which is used as energy in the process. Rayon production as well as the waste generated during rayon production. In addition to observational data, the data needed is the company's historical data regarding the environmental key database. The primary data used include: rayon production process flow, energy consumption data (energy balance), water consumption data, generated emission data and waste, and raw material data used (material balance).

In this study using the LCA method using the SimaPro 9.2.0.2 Faculty License software.

2.2 Research Stages

At this stage, measurement of the impact of the production process on the environment is carried out in one life cycle of rayon fiber products produced for 1 month, which is 2191 tons. The following steps are taken to measure environmental impact with the LCA approach:

Goal and Scope Definition. This stage is the stage of determining the objectives and limitations of the research. Once there is a goal, the scope of the environmental impact assessment is gate to gate because the research is limited, starting from raw materials entering the factory to becoming finished goods.

Inventory of Extraction and Emission. At this stage the decomposition of materials, resources used, and emissions discharged into the environment during the product life cycle is carried out after that, the environmental impact is calculated during its life cycle using SimaPro 9.2.0.2 software.

Impact Assessment. At this stage the determination of the impact on the environment that has been obtained from the Inventory of Extraction and Emission stage is carried out.

Interpretation. After the three stages above have been carried out, the last stage carried out in the Life Cycle Assessment (LCA) method is the interpretation of the three stages. The purpose of this stage is to determine and create solutions for improvement methods that can be implemented effectively and efficiently to reduce the negative environmental impacts caused, namely the determination of environmental improvement hotspots resulting from LCA calculations using SimaPro 9.2.0.2 software.

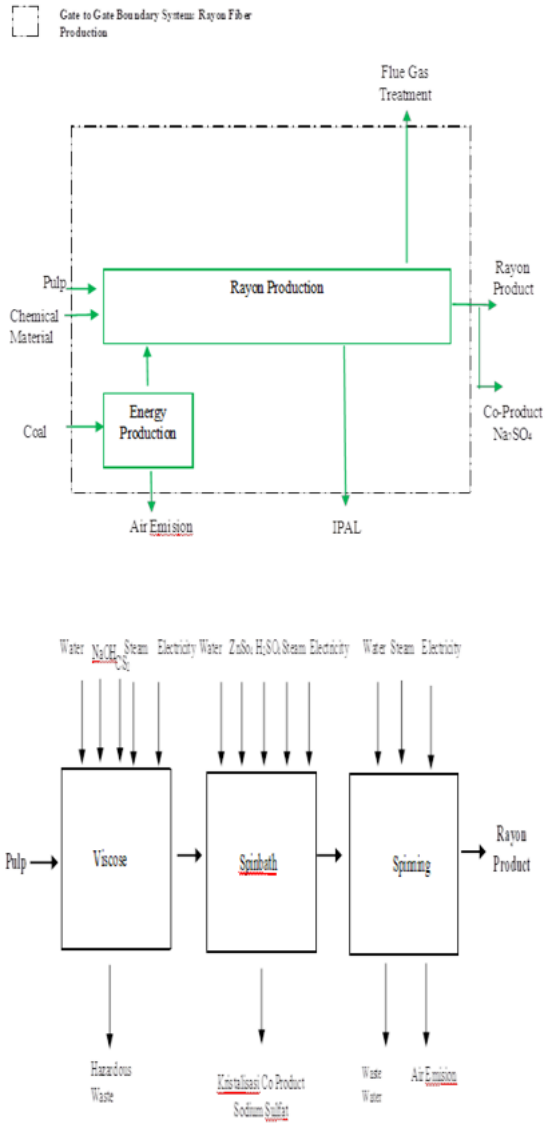

Figure 2: Boundary System Rayon Production

3 RESULT AND DISCUSSION

3.1 Goal and Scope

The goal can determine the category of the highest impact (hotspots) environmental impact on the rayon fiber production process. The scope or limitation used is gate to gate, namely from the process of raw materials entering the factory so that they become rayon fiber products. Stages of inventory per function unit used in rayon production in 1 month. As can be seen in Table 1.

3.2 Life Cycle Inventory

3.3 Characterization

Characterization is a step to directly compare the LCI results in each category. The method used in conducting the environmental impact assessment is CML-IA Baseline V3.06. With this method, 11 categories are produced which include carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer, ecotoxity, acidification, land use, minerals and fossil fuels. The assembly of the production processes that are passed at all stations carries out assessment of the environmental impact of rayon fiber products. The result of the characterization is the environmental impact that is produced on the production of rayon fiber for 21,921 tons of rayon fiber in a period of 1 month that has been packaged. The following results from the characterization of the environmental impact of packaged rayon fiber products or finished products can be seen in Figure 3.

The characterization impact assessment can be displayed in the form of a diagram. The diagram shows the highest impact of the 11 environmental impact indicators, namely Abiotic depletion (fossil fuels) with an impact value of 2.03E+09 MJ and the process of making steam and electricity contributes to the characterization

Table 1: Inventori of rayon production in a year

Input/Output	Total in 1 Year Periode	Unit	Quantity/Function Unit	Unit	The Most Dominant Process
Final Rayon Fiber Mass	263.052	Ton	21.921	Ton	
Rayon Fiber Production System					
Input : Main Raw Material					
Pulp	273.600	Ton	22.800	Ton	Process Production Rayon
Input: Liquid Support Raw Material					
Air	1.072.440	m3	89.370	Ton	Process Production Rayon
NaOH	94	Ton	8	Ton	Process Production Rayon
Input : Solid Supporting Material					
ZnSO4	991,2	Ton	82,6	Ton	Process Production Rayon
H2SO4	198492	Ton	16.541	Ton	Process Production Rayon
CS2	68040	Ton	5670	Ton	Process Production Rayon
Input : Electricity/Steam					
Electricity	129.201.840	Kwh	10.766.820	Kwh	Process Production Rayon
Steam	6876136,8		573011,4	GJ	Process Production Rayon
Input : Solid Fuel					
Batu Bara	555.364	Ton	27.682	Ton	Process Production Energy
Output : Main Product/Co-product					
Serat Rayon	263.052	Ton	21.921	Ton	Process Production Rayon
NaSO4	153.996	Ton	12.833	Ton	Process Production Rayon
Output : Emision to Air					
CO2	12852	Kg	1071	Kg	Process Production Energy
SO2	403980	Kg	33665	Kg	Process Production Energy
Prticulate	30792	Kg	2566	Kg	Process Production Energy

Nox	7722468	Kg	643539	Kg	Process Production Energy
H2S	2641320	Kg	220110	Kg	Process Production Rayon
CS2	9957060	Kg	829755	Kg	Process Production Rayon
Output : Emision to Water					
Chemical Oxygen Demand	1479696	Kg	123308	Kg	Process Production Rayon
Biological Oxgen Demand	579864	Kg	48322	Kg	Process Production Rayon
TSS	460164	Kg	38347	Kg	Process Production Rayon
Zinc	3912	Kg	326	Kg	Process Production Rayon
Sulfate	82943748	Kg	6911979	Kg	Process Production Rayon
Output : Emision to Soil					
-					
Output : Emision to B3 Storage					
Sludge IPAL Ke Disposal to 3rd party	108203200	Ton	9016933,33	Ton	Process Production Rayon
Alkali Cellulose Disposal to 3rd party	3045600	Ton	253800	Ton	Process Production Rayon
Fly Ash Disposal ke Industri Semen	4781,52	Ton	398,46	Ton	Process Production Energy
Output : Waste Non B3					
Tow Disposal ke Industri Semen	421,2	Ton	35,1	Ton	Process Production Rayon
Carton and Paper to 3rd party Scarp	138,6	Kg	11,55	Kg	Process Production Rayon
Wire to 3rd party scarp	771,36	Kg	64,28	Kg	Process Production Rayon

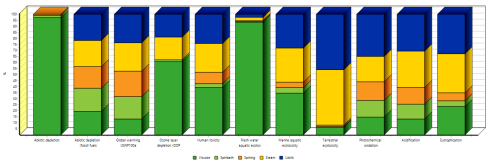

Figure 3: Characterization Impact

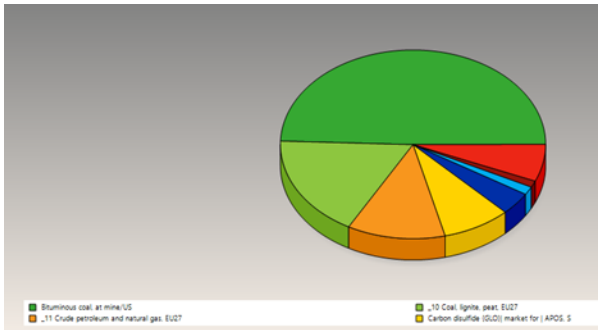

Figure 4: Process Contribution

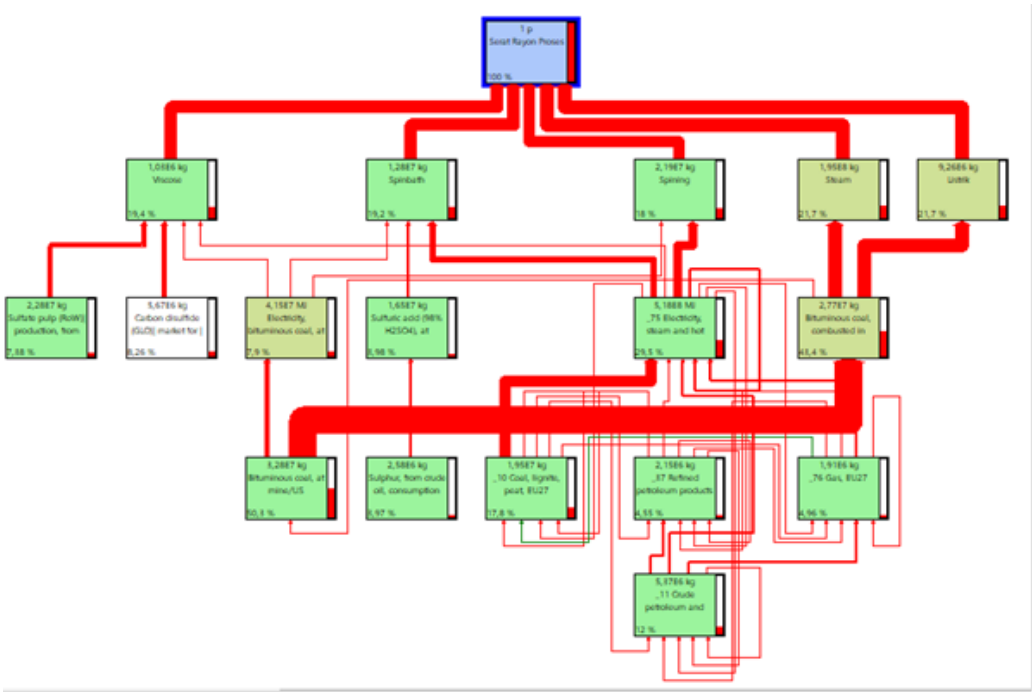

Figure 5: Network LCA of rayon production

impact value. Referring to the PROPER criteria according to the Minister of Environment and Forestry Regulation 01/2021, the impact categories that must be studied are one of the following 5 categories that are used as hotspots for improvement, namely: 1) Global warming potential (GWP value, the largest material contributor, in which process unit), 2) Ozone depletion potential, 3) Acid rain potential 4) Eutrophication potential 5) Energy use (cumulative Energy Demand). The following is the result of the calculation with 5 indicators according to the Minister of Environment and Forestry Regulation 01/2021.

Abiotic depletion (fossil fuels) is the largest contributor to 2.03E+09 MJ. The process's contribution to the impact of Abiotic depletion (fossil Fuels) is seen in Figure 4.

The biggest contribution of bituminous coal at mine or coal of 1E+09 MJ is used in the coal combustion process in boilers which is used as electrical energy and steam for the production process in each viscose, spin bath and spinning production line. Seen in Figure 5 Network, the biggest environmental impact from the characterization of Abiotic depletion (fossil fuels) is bituminous coal at mine.

4 CONCLUSION

From the results of the LCA calculation, it shows that the biggest contribution impact (the hotspot) is abiotic depletion (fossil fuels) of 1E+09 MJ used in the coal combustion process in the boiler which is used as electrical energy and steam for the production process in each viscose, spin bath and spinning production line. As a suggestion for improvement, determination of alternative hotspots for improvement from the results of the following environmental impacts creating new renewable energy or co-firing in the combustion

process in the boiler, there are several alternatives such as biomass or making solar panels for alternative energy used in the production process. For further research, in order to be able to see the environmental impact in the rayon industry from upstream to end users, Cradle to Grave and for further research to use the endpoint method to see the final impact on human health, resources, and ecosystems.

REFERENCES

[1] W. D. Herlinda, "Darurat Optimasi Pasar Lokal Demi Nyawa Industri TPT Nasional," Bisnis Indonesia, 2021. https://bisnisindonesia.id/article/darurat-optimasi-pasar-lokal-demi-nyawa-industri-tpt-nasional (accessed Sep. 25, 2021).

[2] W. M. W. Joanna Bojarska, Patrycja Złoty, "Life Cycle Assessment As Tool For Realization Of Sustainable Development Goals - Towards Sustainable Future Of The World: Mini Review," Acta Innov., no. 38, p. 13, 2021, [Online]. Available: https://www.ceeol.com/search/article-detail?id=972372.

[3] Sekretariat Sustainable Development Goals 2030 Indonesia, "Sustainable Development Goals," European Union, 2017. https://www.sdg2030indonesia.org/page/17-tujuan-sembilan (accessed Sep. 12, 2021).

[4] H. Fitriani, "Kajian Persepsi dan Hambatan Konsultan Perencana Dalam Mengadopsi Konsep Bangunan Ramah Lingkungan The Study of Perception and Barriers of Design Consultant in Adopting the Concept of Green Buildings," vol. 19, no. 2, pp. 1–10, 2021.

[5] F. Rahman, "Penanggulangan Kebakaran Hutan dan Lahan Melalui Instrumen Penaatan Sukarela: (Suatu Tinjauan Dalam Kebijakan Proper Lingkungan) Oleh: Faisol Rahman * 1," no. October, 2019.

[6] SEKRETARIAT PROPER KEMENTERIAN LINGKUNGAN HIDUP DAN KEHUTANAN, "Sosialisasi Mekanisme dan Kriteria Hijau 2021," Sekretariat PROPER Kementerian Lingkungan Hidup Dan Kehutanan, 2021. https://proper.menlhk.go.id/ (accessed Oct. 31, 2021).

[7] W. Benjamin, "Laporan Kunjungan Kerja Spesifik Komisi VII DPR RI ke PT Sritex Sukokarjo & Anak Perusahaannya (Peninjauan Pengolahan Limbah)," 2019.

[8] I. Standard, "International Standard assessment — Requirements and," Int. J. Life Cycle Assess., vol. 2006, no. 7, pp. 652–668, 2006, [Online]. Available: http://www.springerlink.com/index/10.1007/s11367-011-0297-3.

[9] H. Hou *et al.*, "Life cycle assessment of tiger puffer (Takifugu rubripes) farming: A case study in Dalian, China," Sci. Total Environ., vol. 823, p. 153522, 2022, doi: 10.1016/j.scitotenv.2022.153522.

[10] E. I. Wiloso *et al.*, "Life cycle assessment of Indonesian canned crab (Portunus pelagicus)," J. Ind. Ecol. Wiley, vol. 2030, pp. 1–14, 2022, doi: 10.1111/jiec.13276.

[11] G. Borghesi, R. Stefanini, and G. Vignali, "Life cycle assessment of packaged organic dairy product: A comparison of different methods for the environmental assessment of alternative scenarios," J. Food Eng., vol. 318, no. November 2021, p. 110902, 2022, doi: 10.1016/j.jfoodeng.2021.110902.

[12] S. Hasibuan, H. Thaheer, and J. Hidayati. "Life Cycle Impact Assessment of Palm Biodiesel Production toward the Sustainability of Downstream Industry of Indonesia Palm Oil" IOP Conference Series: Materials Science and Engineering Vol. 453, No. 1, p. 012006. IOP Publishing, 2018.

[13] M. P. Tinoco, É. M. de Mendonça, L. I. C. Fernandez, L. R. Caldas, O. A. M. Reales, and R. D. Toledo Filho, "Life cycle assessment (LCA) and environmental sustainability of cementitious materials for 3D concrete printing: A systematic literature review," J. Build. Eng., vol. 52, no. January, p. 104456, 2022, doi: 10.1016/j.jobe.2022.104456.

Green Consumerism in Indonesia

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ABSTRACT

Green consumerism contributes to the preservation of the sustainability development in the future. The use of green products is part of the pro-environmental behavior that plays an important role in reducing the amount of waste, sustainable development, and saving resources. This study aims to determine the effects of attitude, subjective norm, and perceived control behavior on green consumerism in Indonesia with green purchase intention as an intervening variable. This research is a quantitative study by distributing questionnaires to respondents with good understanding of the concept of green or eco-friendly products and data processing is done by path analysis. Results showed that attitude and perceived control behavior affect green purchase intention while subjective norm does not. Attitude, subjective norm and perceived control behavior do not directly influence green consumerism. This study shows that the intention to buy green products and adopt green consumerism is influenced by internal consumer factors.

CCS CONCEPTS

• **Environtment**; • **Business Process Management**;

KEYWORDS

Green, Consumerism, Behavior, Indonesia

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1 INTRODUCTION

In this globalization era, the technology used in industry is increasingly sophisticated and the needs of society are becoming more and more varied. To meet the needs of the community and survive in fierce competition, the company uses various methods and technologies that are owned, both in terms of production, promotion, distribution of products in other ways. Behind the economic and industrial development of companies is getting bigger, it has a bad impact on the earth. Today, environmental issues are being discussed because of the increasingly worrisome condition of the earth, such as the issue of global warming which results in melting of polar ice and forest fires due to overheating weather, pollution, and waste garbage that pollute living habitats and damage land, water and air on earth.

Besides, with the development of technology and an increasingly developing industry, the production process of products becomes easier and more efficient, and the quality of service becomes more effective because of the convenience provided by technological developments. This makes it easier to meet people's needs. But technological and industrial developments also have a negative influence. Society tends not to think long in choosing the products to be used so that it becomes more wasteful and produces excessive waste. In addition, many products are designed to be used only for single use to increase effectiveness and eventually there is a buildup of waste due to overconsumption of these products.

Consumers today are increasingly adopting sustainable consumption habits, evaluating their purchase choices, and preferring brands that are more eco-friendly [1]. Society tends not to think long in choosing the products to be used so that it becomes more wasteful and produces excessive waste. In addition, many products are designed to be used only for single use to increase effectiveness and eventually there is a build-up of waste due to overconsumption of these products.

Globally there are around 2 billion tons of waste produced per year, where the amount of waste produced per person is an average of 0.74 kilograms and 33 percent of them are not processed beforehand to reduce harmful effects on the environment [2]. The total waste produced by the world in 2050 is estimated to reach 3.4 billion tons [3]. As of 2016, the East Asia and Pacific region holds

the first rank in the largest waste producer, reaching 468 million tons and in 2050 the waste increased to 714 million tons per year [4]. One type of waste that is often an issue is plastic. The plastic itself is a strong but lightweight material that can be used for many uses, nevertheless plastic has properties that are not easily decomposed. The other issue is many of the plastic waste is not managed well. Among 8300 million tons, only around 500 million tons of total plastic waste was recycled and 5800 million of plastic waste were only used once, then 4600 million tons are discarded or go straight to landfill [5].

Indonesia is the second largest contributor to plastic waste to the sea after China. Indonesia has a coastal population of 187.2 million which annually produces 3.22 million tons of unmanaged plastic waste [4]. Around 0.48-1.29 million tons of plastic waste are thought to pollute the ocean. The level of plastic waste pollution has increased dramatically due to several business sectors that use a lot of plastic packaging are developing and Chinese policies that prohibit the import of plastic waste so that imports of plastic waste accumulating in Indonesia [3].

Knowing the increasingly worrisome condition of the earth, the global community has finally begun to realize the importance of preserving nature and begin to think about how the products they use contribute the environmental pollution and people. Based on research conducted by the Global Web Index on US and UK communities, most people tend to look for and are willing to pay more for environmentally friendly products. From that research, millennial generation is a group of generations who agree to pay more for environmentally friendly products, which is around 61%. Then followed by generation Z which reached 58%, then generation X as much as 55% and baby boomers as much as 48% [5]. It was also found that some US and UK communities were aware of the contribution they made to the pollution and waste generated. 70% believe that they as individuals have a responsibility in protecting the environment, but as many as 52% also say that the company also has a big role in protecting the environment. Also, as many as 50% say the government also plays a role in protecting the environment [3].

Not only talking about their concern about the future of environmental, the community also took action by buying environmentally friendly products. This can be proven by research conducted by Nielsen, as can be seen in Figure 1.7, sales of environmentally friendly Fast-Moving Consumers Good (FMCG) products in the US are increasing every year. In 2014, sales of environmentally friendly FMCG products reached $ 107.3 million, and for 4 years it continued to increase until 2018 touching $ 128.5 million. Sales of environmentally friendly FMCG products are also predicted to continue to increase.

In Indonesia, based on the survey conducted by Nielsen and World Wildlife Fund (WWF) in 2017 to 916 respondents from Jakarta, Medan, Surabaya, Denpasar, and Makassar with an age range from 15 to 45, it was said that 63% of the respondents are willing to take eco-label products. 61% of the respondents have concerns about global warming effects, environmental responsibility, and the environmental impact of daily consumption [3]. It can be concluded that many of the Indonesian communities have a concern about environmental problems and willing to choose eco-label products.

Changes in consumer behavior in product preferences make companies must think about new innovations to compete and get a competitive advantage [6]. The company sees this phenomenon as a business opportunity as well as building a good image for the company. Companies from various industries began campaigning the go green movement in their marketing and in the design and concept of their products, which then emerged green marketing and green product [7].

The objective of this research is to examine the factors that affect an individual's green purchase intention using Theory of Planned Behavior's variable that contains attitude, subjective norm and perceived control behavior and to examine how an individual's green purchase intention can lead someone to adopt green consumerism.

2 LITERATURE REVIEW

Green marketing is a strategic effort made by the company to provide green and pro-environmental merchandise to their products and service [8]. Green products are products that will not cause pollution to the earth or damage natural resources, and these products can be recycled.

Green advertisements can be defined are advertisements that introduce and promote products, services, ideas, or the ability of organizations to help or reduce environmental damage. Green advertisements describe the promised environmental impacts if consumers use products from brands that promise environmental impacts [9]. Environmentally friendly advertising can be referred to as a symbol that the behavior of a company presented by a brand, is behavior that can be accepted by the public and can build a good image on the company's reputation [10].

Green product is a product that produced under the principle of sustainable development with good quality and are safe to purchase designed, processed and made in a way that can reduce environmental pollution [8]. Materials and production processes use raw materials that can be recycled and are not harmful to the environment and living things

Theory of Planned Behavior (TPB) was discovered by Ajzen in 1985 and is a continuation theory of the theory of reasoned action (TRA), where a decision is determined by factors that influence one's will [9]. According to TPB, an important factor that determines a behavior is how one's intention to engage in the behavior and the behavior is determined by the attitude, subjective norm and perceived control behavior. TPB usually being use for predicting an individual's behavior by measure individual's behavioral intention [10].

Subjective norm refers to the social influence that a person feels and influences someone to take any action or not. Subjective norm can be said is the opinion of someone who influences decision making [10], if someone gets approval or recommendations from someone who has a significant influence on the person, the individual will tend to carry out behavior that is approved or recommended from the closest person. Subjective norm can be a reference point for someone to decide because someone tends to look for and refer to the opinions of those closest to him [10]. The importance of group reference is recognized in subjective norm and also finding out what degree someone can be motivated by group reference [9].

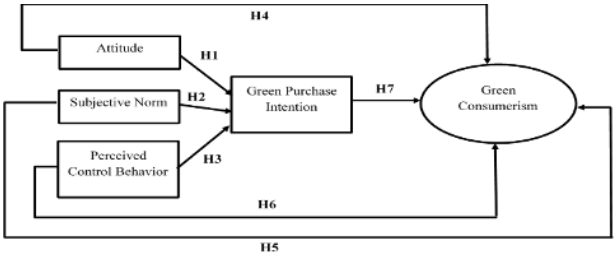

Figure 1: Research Framework

Perceived behavioral control (PBC) is the ease or difficult that a person feels to make an action. Someone who has a higher level of control over themselves will have a stronger intention in carrying out a behavior [11]. PBC can be said as an individual perception, where someone feels that he already has the ability and motivation to take any action, someone will tend to take any action if he has two things, namely ability and motivation compared to if he only has one or not at all [12].

The relationship between attitude and green purchase intention was found in several studies [7]. Regarding the purchase intention of green products in young people in Thailand, there was a significant positive relationship between attitude and green purchase intention, and attitude variable was the variable that gave the most significant influence compared to other variables [12]. Research on purchase intentions for green products in Indian society and green product purchase intentions also proves that attitude variable has a significant positive effect on green purchase intention [11]. This similar relationship also found in [10] research results toward the U.S. community. From these constructs, this study propose the following hypotheses:

H1: Attitude has a significant effect on green purchase intention

H4: Attitude has a significant effect on green consumerism.

There was a significant influence between subjective norm and green product purchase intention of 30.7%, although it had a significant effect, but the effect was not as big as the effect of attitude and perceived control behavior [12]. The significant influence between subjective norm on the purchase intention of green products was also found in [11]. [10] also found that subjective norm has a significant effect on green purchase intention. From these constructs, we propose the following hypotheses:

H2: Subjective norm has a significant effect on green purchase intention

H5: Subjective norm has a significant effect on green consumerism

Perceived control behavior had a significant positive effect on the purchase intention of green products. This was also found in the study [11], The significant effect between the two variables was also found in this research. From these constructs, we propose the following hypotheses:

H3: Perceived control behavior has a significant effect on green purchase intention

H6: Perceived control behavior has a significant effect on green consumerism.

The relationship between green purchase intention and green consumerism can be found in [13]. It was found that green purchase intention has a significant effect on green consumerism. In also revealed that green purchase intention as a determinant of green consumerism. From these constructs, we propose the following hypotheses:

H7: Green purchase intention has a significant effect on green consumerism

3 METHODOLOGY

To measure the green purchase intention and green behavior of consumers in Indonesia, online questionnaire consisting of six segments (attitude, subjective norms, perceived control behavior, green purchase intention, green consumerism, and socio-demographic factors) were distributed randomly to residents who know about the green product concept in Indonesia. There was filtering questions to be sure the respondents are relevant to the topic of this research. Purposive sampling was recruited for this research. The questionnaire was developed based on the review of previous literature and revised by the researchers using a literature review and adjusted for content validity. The results of reliability test depicted the range of data were between 0.787 to 0.895 and it indicated the variables are reliable. For validity test, the data of R count were between 0.720 to 0.930 which supported the validity of questionnaire.

After removing incomplete set of questionnaires, 114 (89.76 percent) valid questionnaires were used to analyze the green behavior of consumers. In addition to the usual descriptive analysis of means and frequencies, path analysis was conducted to estimate the causal relationship between variables. All data processing was conducted using SPSS version 25.0 to address the objectives of this study.

4 RESULT AND DISCUSSION

The profile of respondents depicted majority of respondents were female (62.8 percent). Most of respondents were between 18 to 25 years old (85.1 percent). In terms of occupation most of respondents were student (73.5 percent) and most of them had level of income of less than 2 million Indonesian Rupiah per month. For prerequisite of path analysis, normality test was conducted, and data of Kolgomorov-Smirnov (sig.=.200) depicted the data are normally distributed. Multicollinearity test was conducted to know if there is a correlation between independent variables. Data of VIF (attitude= 1.700, Subjective norms= 1.316, Perceived control behavior=2.351) depicted there are no symptoms of multicollinearity.

From the results in the study, as shown in table 1, the data shows that attitude and perceived control behavior has a significant relationship to green purchase intention while subjective norm does not have a significant relationship with green purchase intention. The results also showed that the three variables have a significant simultaneous relationship to green purchase intention. Each attitude, subjective norm, and green purchase intention do not have a significant effect on green consumerism, but the three variables have a significant relationship simultaneously. Attitude and perceived control behavior can influence green consumerism through green purchase intention variables, but not with subjective norms.

Positive consumer attitudes toward green products positively affect consumers' desire to buy green products. Consumers mean

Table 1: Result of Hypothesis

Path	Sig	Decision
Attitude → Green Purchase Intention	0.000	Ho not accepted
Subjective Norm → Green Purchase Intention	0.947	Ho accepted
Perceived Control Behavior → Green Purchase Intention	0.000	Ho not accepted
Attitude → Green Consumerism	0.751	Ho accepted
Subjective Norm → Green Consumerism	0.105	Ho accepted
Perceived Control Behavior → Green Consumerism	0.249	Ho accepted
Green Purchase Intention → Green Consumerism	0.003	Ho not accepted

that green products are positive, good ideas and green products are safe for them, so they want to buy. Perceived control behavior also has a significant relationship with green purchase intention which means consumers feel able to buy green products and show that consumers have sufficient access to buy environmentally friendly products. The subjective norm variable does not have a significant effect on the green purchase intention variable, which means the role of the closest person to the consumer has less role in increasing the consumer's intention to buy green products. This shows the lack of concern for the people closest to the environment.

Although attitude and perceived control behavior have a significant influence on green purchase intention, these two variables do not significantly influence green consumerism. A positive attitude towards green products and the ability of consumers to buy green products do not make consumers engage in green consumerism activities such as recycling, consuming environmentally friendly products in their daily lives, and buying energy-efficient products. Subjective norms also do not have a significant effect on green consumerism, given the role of the closest people in influencing consumers to buy green products. The green purchase intention variable has a significant influence on green consumerism, indicating that consumers who have a strong desire to buy green products, will practice green consumerism in their routines.

This study also compares the direct effect between attitude, subjective norm, and perceived control behavior on green consumerism and the indirect effect with green purchase intention as an intervening variable. The results of data processing indicate that the indirect effect for the relationship between subjective norm and green consumerism is smaller than the direct effect, while the indirect effect between attitude and perceived control behavior, on green consumerism is greater than the direct effect. It can be concluded that a positive attitude on green products and the ability to buy green products will have a greater influence on consumers to adopt a greener consumption pattern if accompanied by the desire to buy a strong green product.

From the result, it can be concluded that attitude and perceived control behavior are important variables in encouraging consumers to buy green products and the desire to buy green products will also influence consumers to do green consumerism. The impact is given attitude and perceived control behavior will be greater on green consumerism if through a green purchase intention. Subjective norm that does not significantly influence both green purchase intention and green consumerism, which means that the intention to buy green products tends to originate from internal consumers, not from the influence of the closest people. Companies should focus more on increasing the intention that comes from the consumer's internal self.

5 CONCLUSION

To be successful in this market, marketers should understand which factors which affect to green purchase behavior of consumers. Knowing those behavioral factors of consumers can be valuable for marketers to implement better marketing strategy. With fast growing attention to green behavior of consumers in the field of green marketing, the importance of understanding of consumer behavior will become a driving part of most of marketing studies. The main aim of this research was to measure the green purchase intention of residents in Indonesia. The finding of this study indicated attitude and perceived control behavior significantly affect to green purchase behavior and green purchase intention significantly affect to green consumerism. The findings also depicted there is significant relation between subjective norm and green purchase intention as well as there is no significant relation between attitude, subjective norm, and perceived control behavior towards green consumerism.

From these finding it can be concluded that most respondents have positive attitude and perceived control toward green purchase behavior. They also think that green behavior is good to save nature for the next generation. As for subjective norm, it did not show significant relationship with green purchase behavior due to the people around the respondents are not environmentally aware enough to encourage the respondents to practice more environmentally friendly behavior or some of them are aware, but they keep it to themselves, they practice environmentally friendly behavior alone and not encourage other to do the same. Therefore, the subjective norm aspect in this study (family, friends, and neighbor) were not affecting green purchase behavior like the previous studies showed (Chin et al., 2018). Subjective norm is considered as personal factor but since personal factor is not affecting purchase behavior therefore must use physical environment factor such as advertising to target the attention of residents.

It is hoped that the findings of current study will provide valuable insight for stakeholder and organization in Indonesia in evaluating their current operations and formulating their future management and marketing strategies. Furthermore, the aim if marketers should not just be to motivate consumers to purchase green products, but also, they should educate them about the benefits of green behavior and part of societal marketing. In terms of theoretical point

of view, the findings of this study enriched the body of literature in Indonesian context, while identifying the factors affect to their green purchase behavior. These findings could provide a foundation for future studies on this field. As such, the main items that contribute and measure might be used for other aspects of marketing to develop a better understanding about customers' purchase behavior.

REFERENCES

[1] F W Rian, N Gusman, and M Fatimah, 2021. Determinants for Sustainable Green Product Consumption: A Glimpse from Peninsular Malaysia. In Proceedings of 8th International Conference on Advanced Materials Engineering & Technology (ICAMET 2020) AIP Publishing, Lengkawi, MY, 020170-1–020170-9. DOI: https://doi.org/10.1063/5.0054154

[2] CNN Indonesia. 2019. KLHK: 72 Persen Masyarakat Tak Peduli dengan Sampah Plastik. Retrieved from https://www.cnnindonesia.com/teknologi/20190821164641-199-423470/klhk-72-persen-masyarakat-tak-peduli-dengan-sampah-plastik

[3] Nielsen. 2019. Was 2018 the year of the influential sustainable consumer?. Retrieved from https://nielseniq.com/global/en/insights/analysis/2018/was-2018-the-year-of-the-influential-sustainable-consumer/

[4] Hannah Ritchie and Max Roser. 2018. Plastic Pollution. (September 2018). Retrieved March 23, 2022 from https://ourworldindata.org/plastic-pollution

[5] The World Bank. 2019. WHAT A WASTE 2.0 A Global Snapshot of Solid Waste Management to 2050: Trends in Solid Waste Management. Retrieved from https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

[6] Sidi Belo Alkasim, Haim Hilman and Abdul Manaf bin Bohari, 2018. The mediating effect of competitive strategy on the relationship between market development, product development and performance of manufacturing based SMEs in Nigeria. Journal of Business and Retail Management Research 12, 3 (Jan, 2018), 133-141. DOI: https://doi.org/10.24052/JBRMR/V12IS03/ART-17

[7] Aanes Ahmad and K. S. Thyagaraj, 2015. Consumer's Intention to Purchase Green Brands: the Roles of Environmental Concern, Environmental Knowledge and Self Expressive Benefits. Current World Environtment 10, 3 (Dec, 2015), 879-889. DOI: http://dx.doi.org/10.12944/CWE.10.3.18

[8] Dominika Moravcikova, Anna Krizanova, Jana Kliestikova and Martina Rypakova, 2017. Green Marketing as the Source of the Competitive Advantage of the Business. Sustainability 9, 12 (Nov, 2017), 2218. DOI: https://doi.org/10.3390/su9122218

[9] Ezlika Ghazali, Pat Chen Soon, Dilip S. Mutum and Bang Nguyen, 2017. Health and cosmetics: Investigating consumers' values for buying organic personal care products. Journal of Retailing and Consumer Services 39, (Nov, 2017), 154-163. DOI: https://doi.org/10.1016/j.jretconser.2017.08.002

[10] Dooyoung Choi and Kim K. P. Johnson, 2019. Influences of environmental and hedonic motivations on intention to purchase green products: An extension of the theory of planned behavior. Sustainable Production and Consumption 18, (April, 2019), 145-155. DOI: https://doi.org/10.1016/j.spc.2019.02.001

[11] Rambalak Yadav and Govind Swaroop Pathak, 2016. Young consumers' intention towards buying green products in a developing nation: Extending the theory of planned behavior. Journal of Cleaner Production 135, (Nov, 2016), 732-739. DOI: https://doi.org/10.1016/j.jclepro.2016.06.120

[12] Kamonthip Maichum, Surakiat Parichatnon and Ke-Chung Peng, 2016. Application of the extended theory of planned behavior model to investigate purchase intention of green products among Thai consumers. Sustainability 8, 10 (Oct, 2016), 1070. DOI: https://doi.org/10.3390/su8101077

[13] Jana Hojnik, Mitja Ruzzier and Tatiana S. Manolova, 2020. Sustainable development: Predictors of green consumerism in Slovenia. Corporate Social Responsibility and Environmental Management 27, 14 (Jul, 2020), 1695-1708. DOI: https://doi.org/10.1002/csr.1917

Circular Economy in Plastic Pallet Manufacturer (PPM) using Nano Level Material Circularity Indicator (MCI)

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ABSTRACT

The circular economy concept is an industrial system concept with a restorative and/or regenerative design, which is closely related to the material flow. The implementation of a circular economy in a system begins with an initial design based on an assessment of the circularity of the existing system. Of several circularity assessment tools, the Material Circularity Indicator (MCI) was chosen because the assessment is quantitative. The object of this research is Plastic Pallet Manufacturer (PPM) with its main product, namely plastic pallets where the product characteristics are unique, namely between functional products and innovative products. The Nano Level model is implemented to capture material flow at the operational level where PPM has two different flows, namely open and closed in its manufacturing program. Implementing the Nano Model to MCI to conduct an assessment requires adjustments, namely changing the goal from previously assessing a product to assessing a production as a whole. In this study, the implementation of Nano Level MCI succeeded in assessing the production in the latest PPM with an average index of 0.79 which means that the system in PPM is quite circular. Then, the recommendation for improvement with the addition of workstations resulted in an increase in the average index to 0.80.

KEYWORDS

Circular Economy, nano level model, Material Circular Indicator (MCI), circularity, plastic pallets

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1 INTRODUCTION

As humans, we should be concerned about the utilization of most of the resources that still use the take-make-dispose system, which according to Bocken et al, the system can burden and pressure businesses with increased material costs due to scarcity [1].

The Circular Economy concept is proposed as an alternative industrial system that has a restorative/regenerative purpose and design. This concept replaces the 'End of life' with a more effective and efficient cycle system [2].

Saidani et al stated that the Circular Economy model is usually implemented in three-level systems, namely macro level, meso level, and micro level. However, the more specific and detailed the model used, the more relevant it is to the essence or essence of the circular economy, which focuses on the circulation of materials and products [3]. So, Saidani et al, propose a fourth level, namely the Nano Level which can see up to the operational level with material and product flows.

The author takes the object of research at Plastic Pallet Manufacturer (PPM) which produces plastic pallets and several other types of plastic houseware. A pallet is one of the material handlings that serves as a medium between the product and its loading. Pallets are widely used throughout the industry, especially for product delivery [4]. Plastic pallets themselves have unique characteristics as a product because they include several characteristics of functional products and innovative products. And, because there has been no research on circularity in plastic pallet companies, it becomes a bigger reason for the author to carry out this research.

This study aims to evaluate the circularity system in PPM using the Material Circular Indicator (MCI) which has a numerical or quantitative output with a scale of 0 to 1. The nano-level model is also applied in this study to see a clearer picture of the flow of materials and products at the operational level. which company also has two programs with two different types of streams, namely open streams on a regular program, and closed streams on makloan program.

This research is interesting because it is different from previous studies where the circularity assessment using an adjusted MCI does not measure the material flow of the product but the material flow of overall production. So, it is hoped that the results of the circularity assessment can provide an accurate picture of the condition of PPM and can be the basis for providing recommendations for improvement or increasing the circularity scale for the company.

2 LITERATURE REVIEW

Circular Economy according to the Ellen MacArthur Foundation (2015) is an industrial system with a restorative and/or regenerative design, which can replace the linear concept (take-use-throw away) or the 'end-of-life' concept [2]. Meanwhile, according to Geissdoerfer, et al. Circular Economy is a regenerative system that minimizes resources and waste, as well as emissions and other energy leakages

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by slowing, closing, and narrowing the flow of materials and energy [5].

The concept of a circular economy is related to material flows economically and considering the economic conditions that cause these flows [6]. Industry players need to get the right methodology and tools, including the measurement indicators [7].

The need for the development of a framework to track the progress of the Circular Economy was stated by the European Commission in 2018. How the framework is built is to take into account the aspects of the material, product, and service life. And, the framework must contain a set of indicators, which are as follows.

- Production and consumption.
- Waste management.
- Secondary raw materials.
- Competitiveness and innovation.

The implementation of the Circular Economy strategy has the potential to grow the economy, create jobs, and reduce the impact of environmental damage, including carbon emissions [2].

2.1 Circular Business Model

The circular economy concept aims to minimize waste through designing the use of materials, products, etc. through a business model. So that both companies, institutions, and researchers agree that there is a need for an assessment of circularity and indicators that are recognized in industrial practice.

The company's strategic steps should be based on a strong scientific basis. The more specific or detailed the level, the more relevant it will be to the core or essence of a circular economy, which focuses on the circulation of products and materials. So, Saidani et al, propose a fourth level, namely Nano Level, which has a deeper implementation scope. The scope of the Nano Level Model is in operations and products including materials. The introduction and implementation of the Nano Level Model, it is expected to provide a more specific picture for managers.

2.2 Circularity Indicator

The Circular Economy concept, which has direct and indirect advantages, must be measurable so that it can be used as the basis for making future strategies. Therefore, a set of indicators is needed to measure the efficiency of the Circular Economy. Several indicators have been discovered and continue to be developed to help management design their products and systems to be more circular, such as REPRO2, Circular Economy Toolkit (CET), and Circular Economy Indicator Prototype (CEIP), and Material Circularity Index (MCI).

Material Circularity Indicator (MCI) proposed by the Ellen MacArthur Foundation (2015), combines restorative flow measures, with complementary impacts, and risk indicators to create a comprehensive picture. The input to MCI is the product Bill of Materials (BOM) [8]. That is used to measure the extent to which linear flow is minimized and restorative flow is maximized for materials, components, and their duration of use, which are presented in Figure 1. Therefore, MCI uses a rating scale of 0 to 1, because in practice most products will fall between these two extremes.

The variables used in MCI are as follows [2]

1. Amount of pure raw material/virgin(V)
2. The total amount of material that cannot be recovered (W)

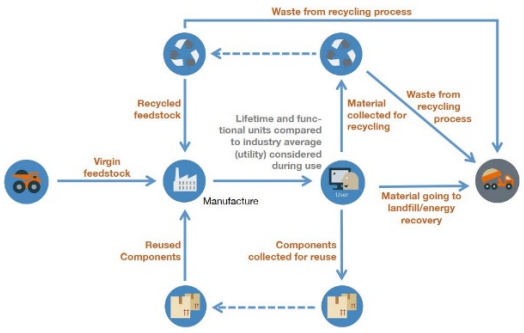

Figure 1: Material Flow Diagram (Ellen MacArthur Foundation, "Circularity Indicators: An Approach to Measuring Circularity," 2015)

3. The proportion of material flow is linear as measured by the Linear Flow Index (LFI) with a scale of 0-1
4. Utility factor (X) which takes into account the phase of product use, and the intensity of product use

2.3 PPM

A product is anything that can be offered in the market to satisfy a want or need, whether in the form of physical goods, services, experiences, events, people, places, properties, organizations, information, and ideas [9].

A company needs to pay attention to several things in designing its products. First, product design must reflect customer or market aspirations. So, there is a need for market research that underlies the making of the design. Second, the designed product needs to take into account the availability and characteristics of raw materials. So, it is necessary to pay attention to who will be the key suppliers. Third, the designed products can be produced economically as much as possible, which is related to the production facilities owned or to be built. Fourth, the product must be designed by considering storage, distribution, and other activities which will also incur costs [10].

Marshal Fisher 1997 divided products into two categories, namely functional products and innovative products. Functional products are products with standard configurations (with few variations) and have long life cycles. Thus, the demand for this product is relatively stable from time to time, making it easy for companies to forecast customer demand in the future. A brief overview of the differences between functional and innovative products is shown in Table 1 [10].

A pallet is a product base/base/holding of goods and/or piles of goods as a medium of transfer and storage in logistics, warehousing, and other activities. Previously, pallets were products made of wood. However, now plastic pallets have become known and are starting to shift the position of wooden pallets. Plastic pallets are considered to have various advantages over wooden pallets.

PPM is one of the companies in Indonesia that is engaged in manufacturing plastic pallets and other houseware products made of plastic, such as plastic baskets, plastic chairs, and so on. The main products from PPM are plastic pallets with various variations,

Table 1: Difference between Functional Products and Innovative Products

Aspect	Functional Products	Innovative Products
Life cycle	> 2 years	Short, 3 months – 1 year
Variations per category	Few, 10-20 variants	Many, thousands
Volume per production	High	Low
Demand Forecasting	Relatively easy, high accuracy	Difficult to predict, high error rate
Stock out rate	1-2%	10-40%
Excess inventory at the end of sales	Rarely, because the sales period is relatively long	Often
Markdown	Almost 0%	10-25%
Profit margin per unit	Low	High

Table 2: Product Characteristics of PPM's Plastic Pallet

Aspect	Functional Product	Innovative Product
Life cycle	X	
Variations per category		X
Volume per production	X	
Demand Forecasting		X
Stock out rate		X
Excess inventory at the end of sales		X
Markdown	X	
Profit margin per unit	X	

both in size, strength, color, and others. PPM has around 30 main product variants that they offer. The variants presented do not include custom requests, such as adding customer identity with spray paint, hot stamps, and so on. So that the characteristics of PPM products are unique because they have the characteristics of functional products and innovative products, as presented in Table 2.

PPM uses two types of plastic as its main base material, namely High-Density Polyethylene (HDPE) and Polypropylene (PP). Both HDPE and PP have different characteristics that cause them to have their own advantages and disadvantages.

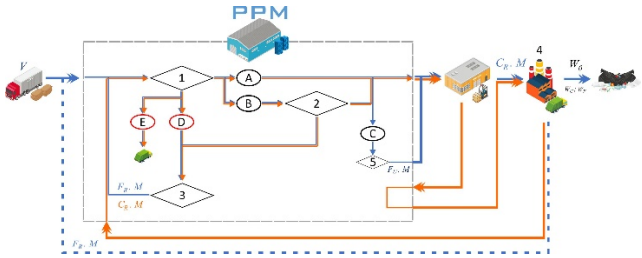

Figure 2: PPM's Nano Level MCI Model

3 METHODOLOGY

This paper attempts to answer the research questions:

1. How do assess the condition of circularity in PPM?
2. What are the recommendations for improving the circularity value for PPM?

To address that questions, Material Circularity Indicator (MCI) was chosen as a research tool because of its quantitative nature. While the Nano Level model is implemented to capture material flow at the operational level where PPM has two different programs. Thus, in this study, an assessment of the circularity of PPM using Nano Level MCI was carried out where the MCI was adjusted not to measure the flow of product material but rather the material flow of overall production. However, the order of assessment still follows the MCI presented by EMF.

4 RESULT

PPM is a plastic pallet manufacturing company. PPM has shipped its products both domestically and abroad. PPM operates on an order basis or MTO, which only works when the customer has placed an order through 2 programs, namely regular and makloan.

PPM has 2 products, namely basic and modified products. Basic products are products that are only processed by a molding machine. Modified products are products with the process of installing accessories, as well as reducing/cutting products according to customer requests. The entire production process at PPM is shown in Figure 2.

The basic pallet is the main component which can also be sold directly without the need to go through a modification process. The basic pallets can be made from raw materials which can be prime/virgin plastic pellets, crusher chips, and for some customized products, additional materials such as dyes, flexors, reinforcements, and so on are needed.

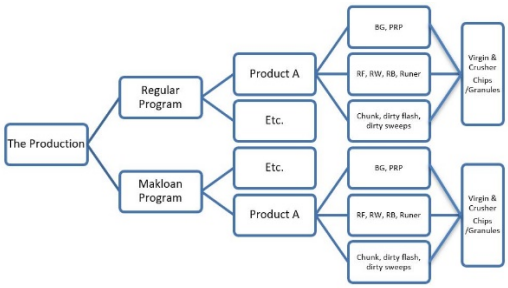

Figure 3: PPM's production

Although theoretically plastic-based products can be recycled and made repeatedly, there is always a heavy reduction in the waste recycling process which also depends on the capacity and efficiency of the recycling machine. So, in this study, the author tries to measure the company's MCI based on a manufacturing index per pallet type. This assessment is limited by the use of basic plastic pallet manufacturing data for the period 2021.

4.1 MCI Tools Adjustment

MCI as a tool presented by EMF in its circularity calculation methodology is widely used to measure the circularity index of a product. However, based to the Ellen MacArthur Foundation (2015), the methodology presented makes it possible to assess the circularity of a company. So that it is expected to be able to help the company to understand the condition of the company or the extent to which the company has transformed into a circular company.

PPM has many types of basic products, namely plastic pallets without accessories of various sizes, load-bearing capacities, and others. In addition, PPM also provides the option of adding accessories to meet customer needs. There are quite a several product types in PPM with various combinations of accessories offered, making it difficult to assess and draw conclusions that can accurately represent the conditions at PPM that are shown in Figure 3.

So, it is necessary to adjust the MCI tool to nano level to assess circularity in PPM through basic pallet production data. Thus, the adjustment of the tool to be more suitable for assessing accessible data from PPM is shown in Figure 3.

In this adjustment, the production results both in good condition and rejected are considered as components of the assessment. M, which is defined as the total mass of the product, is converted or considered as the total mass of production. This also applies to other assessment components, such as the recycled fraction, reused fraction, recycled feedstock fraction, and others.

4.2 MCI Measurement for Existing Condition

As previously explained, PPM has two main programs, namely the regular program and the makloan program. Thus, to see the actual condition of the PPM, each of these programs must be calculated using a predetermined assessment tool, namely the Nano Level MCI.

Therefore, the MCI calculation is used to measure manufacturing performance in PPM. And, this calculation begins by grouping production data for the 2021 period which was previously per work shift into per product. Then, the data will be entered into the MCI calculation. Production data for the 2021 period through the regular program is shown in Table 3.

4.2.1 Calculating Virgin Feedstock. Virgin material is material that has not been used or consumed before [2]. Plastic pallets at PPM use plastic raw materials in the form of prime pellets and/or crusher chips that are recycled from reject products and processing residues, as well as additional materials such as dyes, reinforcements, flexors, and others. Prime materials and additives are included in the category of virgin materials.

The MCI calculation assesses material flow concerning mass. So, to carry out calculations using actual data in the field in the form of the total mass of production. And, with the nano model applied in this study, the fraction of recycled raw materials are taken from raw material data from internal PPM and from third parties that are already in a ready-to-use condition, while the fraction of reused raw materials is worth 0 because there is no raw material produced from reuse in the basic pallet molding process.

$$V = M - MF_R - MF_U \tag{1}$$

Based on the measurement, there are still virgin materials used in the Makloan program, but the virgin materials are not in the form of prime pellets but are changed to additional materials as reinforcement and flexibility according to customer needs which cannot be achieved if using 100% recycled materials.

4.2.2 Calculating Unrecoverable Waste. The advanced formula from MCI is a formula for calculating non-recoverable waste. This waste can arise due to the recycling and reuse of products, including during pre-process collection activities. In the pallet molding process, there are several by-products in the form of formation rejected pallet (RF), color rejected pallet (RW), weight rejected pallet (RB), and several types of afvalans.

In this research, C_R is the mass fraction of the product which is collected after the end of the usage period for recycling. Furthermore, the calculation of the quantity of waste in the recycling process is carried out with the W_C formula. To calculate the quantity of waste in the recycling process, a recycling process efficiency (E_C) value is needed, where the efficiency value is obtained from the historical performance of PPM's Crusher Machine so that based on the average it can be determined that the E_C is 0.997.

Whereas, the calculation of waste generated to produce any recycled used as feedstock (W_F) is carried out to calculate the efficiency of the recycling process, which in this study uses efficiency based on contract documents because the recycling process is carried out by third parties through services. So, E_F is 0.92.

The calculation of unrecoverable waste using the formulas below.

$$W_0 = M\ (1 - C_R - C_U) \tag{2}$$

$$W_c = M\,(1 - E_c)\,C_R \tag{3}$$

$$W_F = M\,\frac{(1 - E_F)\,F_R}{E_F} \tag{4}$$

4.2.3 Calculating the Linear Flow Index. The LFI measures the proportion of material flow linearly, including virgin material flows, and ends up partially as non-recoverable waste. So, based on the previous calculation, LFI can be calculated by dividing the amount

Table 3: Mass of production in the 2021 period

Product	M (ton)	Fr	Product	M (ton)	Fr
PT 1210AS	1577.48	.74	PF 1311	173.35	.84
PR 1512	1055.01	.17	CF 1210	144.87	.95
CF 1111	948.93	.97	TSH 1210	112.05	.37
PF 1210	597.24	.04	BST 1211	101.27	.10
2C1312	414.89	.04	PR 1311	91.12	.30
BST 1210	337.90	.17	B1110	75.65	.00
B325	332.88	.66	CPF 1111	69.45	.86
2C1513	315.36	.06	BT 1210	64.52	.75
B126	309.77	.64	C527	62.87	.21
B125v2	267.70	.57	TSH 1211	59.29	.15
PF 1111	196.23	.93	TSH 1210v1	47.08	.21
B113	190.62	.94	B1111	33.80	.73
PT 1212	189.19	.52	B1210	31.20	.53
C1513	184.97	.02	CB 1212	9.13	.03
CPR 1111	179.27	.84	PF1311 [M]	21.30	1.0
BSF 1210	173.50	.03	PT1210AS [M]	19.92	.97

of material flowing linearly by the amount of restorative flow. The index is worth from 1 to 0, where index 1 means the flow is completely linear while index 0 the flow is completely restorative.

$$LFI = Linear\ Flow\ Index = \frac{V + W}{2M + \frac{W_F - W_C}{2}} \tag{5}$$

4.2.4 Calculating the Utility Factor. The calculation of utility X consists of two components, namely the length of the phase of product used against the average use of similar products, and the intensity of product use against the average use of similar products. The two components are combined to calculate the formula X.

In this utility calculation, the pallet product itself cannot be determined by the maximum usage limit, so the factor of the intensity of use for both PPM products and the average of similar industrial products can be considered to be worth 1.

As for the product age factor for similar industrial products, PPM products are designed to be durable, which is more than five years. Thus, the age factor for both PPM products and the average of similar industries can be set to be worth 5 years. So, the pallet utility calculation is as follows.

$$X = \left(\frac{L}{L_{av}}\right) \tag{6}$$

4.2.5 Calculating the Material Circularity Indicator. MCI can be calculated after obtaining the LFI and F(X) values, which will affect the MCI value later. MCI has an index value of 0 to 1. However, according to EMF (2015), there is no truly linear industry, so calculating the maximum MCI rating starts from 0.1 [2]. Meanwhile, the equation used to calculate MCI is as follows. The MCI values for all products are shown in Table 4.

$$MCI = 1 - LFI \cdot F(X) \tag{7}$$

Based on Table 4, it is known that 25 of the 32 products have a manufacturing MCI value of more than 0.5 which can be said that manufacturing in PPM, in general, can be said to have been circular. If grouped by manufacturing program in PPM, then the Makloan program has a better average MCI score of 0.93, while the regular program has an average value of 0.66. So, overall PPM has an average MCI index of 0.79.

The production through the Makloan program has a relatively high MCI value. This is due to the dominant use of recycled materials, even PF 1311 Makloan uses 100% recycled materials. However, in its production there are still rejected products, so the index value is still 0.94. This means that the index can still be improved.

4.3 Circularity Index Improvement Proposal

In calculating the material flow for pallet production at PPM, several factors influence, and in the calculation of MCI production this time, there are still product rejects. The product with the lowest MCI value is C1513, which has a product reject percentage of 35.7% of the total mass production. Although the rejected products at PPM can be recycled, there is always shrinkage or loss in the collection and recycling process.

So, to increase the circularity index of production at PPM is by reducing the number of rejects or preventing the occurrence of rejected products. Meanwhile, RW or color rejects are the most likely to be repaired as the basis for increasing the MCI index. The main cause of RW is due to the use of crusher material, while RF and RB are more often caused by incorrect machine settings. To improve MCI through RW improvement, the author recommends adding a workstation with a color sorter investment. Plastic Color Sorter is a sorting device for plastic granules or pieces. The color sorter is placed before entering the injection machine area, or in the raw material warehouse for the re-bag process

However, to find out the possibility of RW reduction performance, a color sorter machine is selected according to the capacity of the crusher machine and various related matters such as electricity, space area, and so on. So, try to choose from the website wesortcolorsorter.com (accessed June 21, 2022) one product, namely the Seven-channel plastic color sorter. It is assumed that the sorting

Table 4: Result of MCI calculation

Product	MCI	Product	MCI
CF 1111	0.93	PR 1311	0.58
CF 1210	0.92	TSH 1210v1	0.57
B113	0,91	C527	0.57
PF 1111	0.89	TSH 1211	0.54
CPF 1111	0.87	BST 1210	0.54
CPR 1111	0.84	PR 1512	0.53
PF 1311	0.84	BST 1211	0.52
PT 1210AS	0.82	2C1513	0.50
BT 1210	0.80	2C1312	0.49
B325	0.77	B1110	0.49
B1111	0.76	PF 1210	0.44
B126	0.75	CB 1212	0.42
B125v2	0.71	BSF 1210	0.41
PT 1212	0.66	C1513	0.33
B1210	0.66	PF 1311 Makloan	0.94
TSH 1210	0.63	PT1210AS Makloan	0.92

accuracy of the color sorter is the ability to reduce RW, which is 99% according to the machine provider's claim.

The calculation of the improvement proposal in this research is to continue using the total production in the 2021 period. Only RW will be reduced by 99% of what is produced in that period. The calculation result of this scheme is quite good because it can increase the MCI index of the C1513 product from 0.33 to 0.42. Although, with this scheme, only one of the seven products can exceed the 0.5 indexes.

5 CONCLUSION

After going through the process of completing this research, the following conclusions can be drawn.

1. The MCI tool can be adapted to measure the product material flow index to measure the production/manufacturing material flow. So, with calculations using Nano Level MCI, it can measure the company's material flow seen from the basic manufacture of plastic pallets. And, the result of measuring the company's performance using MCI in the current condition is 0.79.
2. The improvement proposal to increase the index by reducing the quantity of color reject pallets (RW) by installing a pellet color sorter is quite capable, because it can increase the C1513 product index by 27%, from 0.33 to 0.42. And, overall increased the basic pallet production index in PPM from 0.79 to 0.80.

REFERENCES

[1] N. M. P. Bocken, S. W. Short, P. Rana, and S. Evans, "A literature and practice review to develop sustainable business model archetypes," Journal of Cleaner Production, vol. 65. pp. 42–56, Feb. 15, 2014. doi: 10.1016/j.jclepro.2013.11.039.

[2] Ellen MacArthur Foundation, "Circularity Indicators: An Approach to Measuring Circularity," 2015. [Online]. Available: http://www.ellenmacarthurfoundation.org/circularity-indicators/.

[3] M. Saidani, B. Yannou, Y. Leroy, and F. Cluzel, "How to assess product performance in the circular economy? Proposed requirements for the design of a circularity measurement framework," Recycling, vol. 2, no. 1, 2017, doi: 10.3390/recycling2010006.

[4] S. Adsavakulchai, "Optimization of Pallets Management for Circular Economy," 2021. [Online]. Available: www.jraspublications.org/index.php/JRAS/issue/archive

[5] M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, "The Circular Economy – A new sustainability paradigm?," Journal of Cleaner Production, vol. 143. Elsevier Ltd, pp. 757–768, Feb. 01, 2017. doi: 10.1016/j.jclepro.2016.12.048.

[6] P. Ekins, T. Domenech, P. Drummond, R. Bleischwitz, N. Hughes, and L. Lotti, "Managing environmental and energy transitions for regions and cities How and Where Background information Managing environmental and energy transitions for regions and cities The OECD Centre for Entrepreneurship, SMEs, Regions and Cities on Twitter: @OECD_local Citation," 2019.

[7] Y. Geng, J. Fu, J. Sarkis, and B. Xue, "Towards a national circular economy indicator system in China: An evaluation and critical analysis," J Clean Prod, vol. 23, no. 1, pp. 216–224, Mar. 2012, doi: 10.1016/j.jclepro.2011.07.005.

[8] M. Dwek, "Integration of material circularity in product design," 2018. [Online]. Available: https://tel.archives-ouvertes.fr/tel-01737551

[9] P. Kotler and K. L. Keller, Marketing management, 15th ed. Pearson Education, Inc., 2016.

[10] I. N. Pujawan and M. Er, Supply Chain Management (Edisi 3), 3rd ed. Yogyakarta: ANDI, 2017.

Analysis of Water in Oil Emulsions Effect from Used Engine Lubricant Oil Potential Material for EOR Heavy Crude Oil

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ABSTRACT

Emulsions of Water-in-Oil (W/O) have been shown to be an effective driving fluid for heavy crude oil recovery (>100cp) in sandstone flooding experiments with almost achieved 100% recovery. This emulsion is stabilized by oleophilic nanoparticles without the need of surfactants. However, finding an oil with cheap and easily available to create an emulsion is not easy. This paper introduces the trial blend of W/O emulsions with a very common material, namely used engine lubricant oil. More than one billion liters of engine lubricant oil are used in Indonesia every year and has become a major contributor to pollution due to improper use at its disposal. In other ways, this used engine lubricant oil can be an excellent candidate for making emulsions W/O. First, the detergents, the acidity and soot (organic carbon) from the decomposition of engine oil lubricants provides perfect solid particles to stabilize the emulsion; secondly, the medium viscosity allows optimal viscosity to be achieved when blending the emulsion; and the third, nanoparticles from oxidized wear metal from engine debris can help also to reduce the IFT of heavy oil.

CCS CONCEPTS

• **Waste treatment**;

KEYWORDS

Water in oil emulsion, used engine lubricant oil, surfactant flooding, emulsion stability, viscosity, and mobility ratio

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1 INTRODUCTION

Heavy oil constitutes the largest part of the world's oil reserves [6, 7]. However, it is much more difficult to produce compared to conventional, due to its high viscosity. Primary production only recovers about 5% of heavy oil on the spot. With water flooding, only 5~10% of the oil can be produced before the economic limit is reached [11] .

One of the driving fluids by adding polymers to the water injected into the reservoir is the most efficient way to increase the viscosity of water. It is commonly used for the reacquisition of oil with low to medium viscosity (approx. <100 cp) and many fields are successful with polymer flooding applications which has been reported from different reservoirs in the world. For the recovery of heavy oils using polymers requires very high concentrations of polymers for highly viscous oils, and the cost of chemicals increased along with the difficulty of injection will make this process uneconomical [17].

Alkaline-surfactant (AS) flooding is another driving fluid research method for heavy oil recovery. Surfactants decrease the interfacial tension (IFT) between crude oil and water, while alkalis react with the acidic components of the crude oil and create surfactants inside the reservoir. Lowering the IFT not only reduces the capillary trap of the oil component, but also increases the ratio of mobility by formation of oil and water emulsions [15] .

Emulsion flooding is closely related to Alkaline Surfactant Flooding, rather than emulsifying oil in a reservoir, it is better that an emulsion is produced above the ground and then injected into the formation. This way the emulsification process can be better controlled by mixing a certain ratio of chemicals and applying sufficient mixing. Crude oil is usually used due to its availability in the field.

The type of emulsion (W/O or O/W) produced depends on a number of factors [8, 9].

This paper will be focus on how we can get good composition of emulsion W/O solution from used engine lubricant oil mixed with synthetic brine water and the emulsion solution compatible with heavy crude oil.

2 LITERATURE REVIEW

2.1 Engine Lubricant oil

Engine lubricant oil consists of hydrocarbons, the formulation of this engine lubricant oil consists of base oil and viscosity improver (72-96%) and additive package (4-28%) [16]. In detail, engine lubricant oil formulations for gasoline usually contain one to two dispersants, one or two detergents, antiwear agents, oxidation inhibitors, corrosion inhibitors, foam inhibitors, viscosity modifiers, and pour point depressants [16].

Composition of Gasoline Engine Lubricant oil.

Material	Weight (%)	Material	Weight (%)
SAE 30 or 40 base oil	71.5 to 96.2	Antioxidant/ Wear	0.1 to 2.0
Metallic detergent	2 to 10	Friction modifier	0.1 to 3.0
Ashless dispersant	1 to 9	Anti-foam agent	2 to 15 ppm
Zinc dithio-phosphate	0.5 to 3.0	Pour point depressant	0.1 to 1.5

Type of Engine Lubricant oil Detergent: Sulfonate, Phenate, Salicylate and Phosphate. [16] .

Type of Detergent	Chemical Formula*
Neutral Sulfonate	$(RSO_3^-)_2 M^{2+}$
Carbonate-sulfonate micellar compound	$(RSO_3^-)_2 M^{2+} \cdot (M^{2+}CO_3^{2-})_x$
Synthetic Sulfonate	$R'H_2CRHC\text{-}C_6H_4\text{-}CO_3^-)_2M^{2+}$
Normal Phenate	$(R\text{-}C_6H_4\text{-}O^-)_2M^{2+}$
Salcylate	$(R\text{-}C_6H_4\text{-}ROO^-)_2M^{2+}$
	$^aM^{2+}$ = Ca, Mg
	O O O S
Phosphonates:	| || | ||
(1) Phosphonate	R-P-O R-P-S-P-R R-P-O
(2) Thiopyrophosphonate	| | | I I
(3) Thiophosphonate	O-M O-M-O O-M
	(1) (2) (3)

At low concentrations, the detergent absorbs on the surface of the solvent, with one segment dissolved in the solvent and the other segment in contact with air. Which segment contacts the solvent depends on whether the solvent is hydrophilic or lipophilic. In hydrophilic solvents, the polar group is in contact with the solvent, while the lipophilic chain is in contact with air. Its structure is reversed in lipophilic solvents [13].

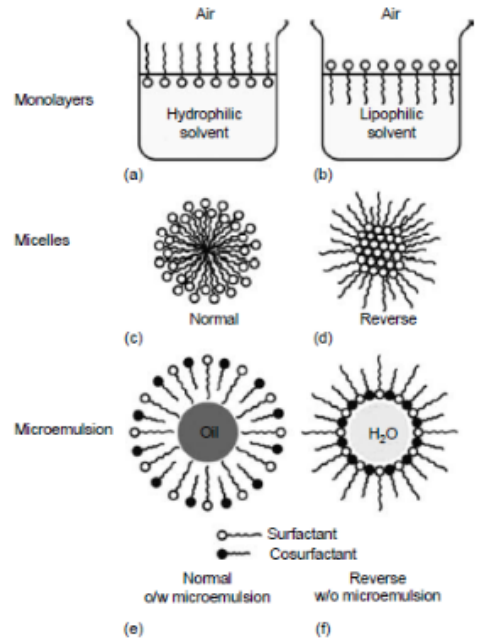

Figure 1: The microstructure of the surfactat assembly in solution

Engine lubricant oil is used under high temperatures and there is often oxidation friction that occurs. Oxidized compounds such as acids can reduce IFT, and soot (organic carbon) can provide oleophilic [2, 3]. Nanoparticles derived from gram-gram wear metal can serve to stabilize emulsions when emulsions are formed [1].

About 1 billion liters of used engine lubricant oil are wasted in Indonesia every year. They must be recycled to avoid contamination of the environment. It is estimated that one liter of lubricant oil used by the engine can pollute a million gallons of fresh water. Currently, almost every workshop and industry is a source of lubricant oil used for machines. The collected oil will be distilled into lubricant or simply burned as fuel for energy (Global Used Oil and Re-Refined Lubricants). In general, used lubricant oil is more of a pollution problem than useful as a recycled raw material. This paper introduces the potential use of used lubricant oil to produce W/O emulsions for EOR heavy crude oil.

2.2 Enhance Oil Recovery (EOR)

Enhance Oil Recovery (EOR) from heavy oil reservoirs with low permeability is a classic problem in the field of oil chemistry [18]. One of the main obstacles is the high mobility ratio, and poor injectivity in heavy oil reservoirs with low permeability [4].

2.3 Oil Recovery

Oil Recovery (E_R) is defined as the ratio of total oil produced to oil reserves [5],

$$E_R = E_V \cdot E_D \tag{1}$$

Where, E_R stands for oil recovery.

E_V = volumetric sweep efficiency.

E_D = oil displacement efficiency).

2.4 Displacement Efficiency (IFT and Capillary Number)

The chemical added in the injection water reduces the IFT of the oil/water and changes the wettability of the rock, which leads to improved oil recovery [10, 12]. The dimensionless capillary number (Ca 1/4 vl=c, where v and l are the speed and viscosity of the injected liquid, respectively, and c is the IFT between the two phases) is the ratio of the viscous force to the capillaries. Ca correlates with oil recovery, and certain previous values of Ca lead to an almost complete oil recovery

2.5 Total Acid Number (TAN)

Total Acid Measurement is the titrating of heavy oil with an alcohol solution of Potassium Hydroxide (KOH) used to neutralize the acid in grams of oil, also called the neutralization number or acid number [14]. Tests that detect TAN in crude oil are:

1. ASTM D974 Methods (Colorimeter Methods).
2. ASTM D664 Methods (Potentiometer Methods).

2.6 Sweep Efficiency (Mobility ratio)

The described concept of mobility ratio is defined simply as the mobility of the transfer of the phase to the mobility of the movable phase. [5].

$$M_{w-0} = \frac{k_w \mu_0}{k_0 \mu_w} \tag{2}$$

Where:
k_w = permeability of driving fluid
μ_o = viscosity of the displaced liquid
k_o = permeability of the displaced fluid
μ_w = viscosity of the driving fluid

3 METHODOLOGY

The research conducted is an experimental study in the laboratory to test compatibility (Viscosity, Density, and IFT test), stability emulsion test, and core flooding test. The material of this study is engine lubricants from the surrounding environment, namely: Gasoline PCMO Engine Oil SAE 0W20 API SN, Lubricant oil used engine engines, synthetic brine water, and heavy crude oil.

Stage of research consists of:

- Preparation all materials of used engine lubricant oil (Passenger Car Motor Oil), Sample heavy crude oil API18.
- Manufacture of synthetic brine by dissolving 30000ppm NaCl into aquadest
- Emulsion manufacturing from W/O concentration 20%, 40%, 50%, 60% and 70%:
- Used lubricant oil in place in the container first
- Brine is entered slowly and then start mixing with a silverstone mixer at a speed of 5000 rpm until the brine reaches 60% of the volume for 5-10 minutes
- Laboratory Test/compatibility characteristics
- Viscosity and Density of heavy oil and emulsion solution in units of cP
- Interfacial Tension (IFT) heavy oil after interacting emulsion solution

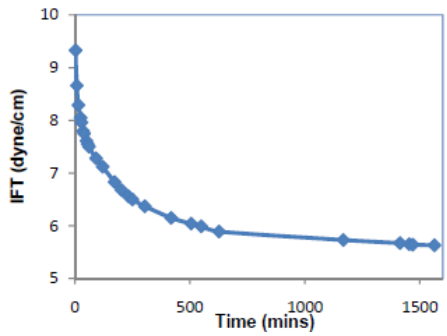

Figure 2: The result of the change in the IFT of the emulsion solution

4 RESULTS AND DISCUSSION

4.1 Emulsion Solution Stability Test

After stirring at a rate of 5000 rotary per minute, the color of the emulsion solution changes rapidly from black to light brown, and the viscosity increases quite significantly by about 75% and increases in line with the addition of its water concentration, and it is obtained a stable condition in the solution emulsion from used engine lubricant oil with water concentrations of 20%, 40%, 50%, 60%, and 70% on the ambient storage test for 4 months.

4.2 Compatibility Characteristics Test

Obtained the characteristics of the emulsion solution from the used engine lubricant oil with water concentration of 20%, 40%, 50%, 60%, and 70% have a minimum viscosity equal to the viscosity of the sample heavy crude oil which is optimal at the mobility ratio and is consistent at brine salinity of 30,000 ppm. The increase in the value of soot, oxidation and wear metal content in used engine lubricant oil compared to the new lubricant will be directly proportional to the result of the IFT decrease in heavy crude oil.

5 CONCLUSION

Based on the results of the research to determine the optimum characteristics of the emulsion solution from used engine lubricant oil to produce an optimum recovery factor, it can be concluded:

1. Water in oil emulsion solutions of 50%, 60%, and 70% have more stable emulsion properties than water in oil 20% and 40%.
2. In compatibility testing, the results from the most appropriate emulsion fluid composition, have a good mobility ratio, can decrease IFT and compatible with injected heavy crude oil samples.

REFERENCES

[1] Arab, D., Kantzas, A., & Bryant, S. L. (2018a). SPE-190212-MS Nanoparticle-Enhanced Surfactant Floods to Unlock Heavy Oil. http://onepetro.org/SPEIOR/proceedings-pdf/18IOR/5-18IOR/D051S027R004/1231789/spe-190212-ms.pdf
[2] Arab, D., Kantzas, A., & Bryant, S. L. (2018b). SPE-190377-MS Nanoparticle-Fortified Emulsification of Heavy Oil. http://onepetro.org/SPEOGWA/proceedings-pdf/18OGWA/2-18OGWA/D022S002R002/1239617/spe-190377-ms.pdf

[3] Barnes, J. R., & Buijse, M. A. (2012). SPE 154084 Controlled Hydrophobe Branching to Match Surfactant to Crude Oil Composition for Chemical EOR. http://onepetro.org/SPEIOR/proceedings-pdf/12IOR/All-12IOR/SPE-154084-MS/1638411/spe-154084-ms.pdf/1

[4] Bazazi, P., Gates, I. D., Nezhad, S., & Hossein Hejazi, S. (2017). SPE-185008-MS Silica-Based Nanofluid Heavy Oil Recovery A Microfluidic Approach. http://onepetro.org/SPECHOC/proceedings-pdf/17CHOC/2-17CHOC/D021S006R002/1277994/spe-185008-ms.pdf

[5] Chatzis, I., & Morrow, N. R. (1984). CORRELATION OF CAPILLARY NUMBER RELATIONSHIPS FOR SANDSTONE. Society of Petroleum Engineers Journal, 24(5), 555–562. https://doi.org/10.2118/10114-PA

[6] Fu, X., & Lane, R. H. (n.d.). SPE 162633 Water-in-Oil Emulsions: Flow in Porous Media and EOR Potential. http://onepetro.org/SPEURCC/proceedings-pdf/12CURC/All-12CURC/SPE-162633-MS/1651631/spe-162633-ms.pdf/1

[7] Fu, X., & Mamora, D. (2010). SPE 129902 Enhanced Oil Recovery of Viscous Oil by Injection of Water-in-Oil Emulsion Made with Used Engine Oil. http://onepetro.org/SPEIOR/proceedings-pdf/10IOR/All-10IOR/SPE-129902-MS/1769958/spe-129902-ms.pdf/1

[8] Ghloum, E. F., Rashed, A. M., & Al-Attar, M. A. (2015). SPE-172732-MS Characteristics and Inversion Point of Heavy Crude Oil Emulsions in Kuwait. http://onepetro.org/SPEMEOS/proceedings-pdf/15MEOS/All-15MEOS/SPE-172732-MS/1394559/spe-172732-ms.pdf/1

[9] Ghloum, E., Rashed, A., Al-Jasmi, A., Al-Ali, A., Mali, P., & Sanyal, A. (2015). SPE-175312-MS Selection of Suitable Viscosity Reducer to Facilitate Test Production of Heavy Oil and Deep Reservoir. http://onepetro.org/SPEKOGS/proceedings-pdf/15KOGS/All-15KOGS/SPE-175312-MS/1443356/spe-175312-ms.pdf/1

[10] Hirasaki, G. J., Miller, C. A., & Puerto, M. (2008). SPE 115386 Recent Advances in Surfactant EOR. http://onepetro.org/SPEATCE/proceedings-pdf/08ATCE/All-08ATCE/SPE-115386-MS/1795775/spe-115386-ms.pdf/1

[11] Kirsch, M.-A., Brugger, M., Philp, L., Elliott, K., Stenson, J., Schuldhaus, K., Wickel, P., Sankey, G., Hill, C., Rahnama, F., Crowfoot, C., Macgillivray, J., Stonkus, O., Bourgaize, J., Logan, K., Kelly, G., de Grace, R., Communications, ;, & Curran, B. (2007). ST98-2007: Alberta's Energy Reserves 2006 and Supply/Demand Outlook 2007-2016.

[12] Li, Z., Lu, Y., Wu, H., Yang, M., Feng, H., Xu, D., Hou, J., Kang, W., Yang, H., & Zhao, Y. (2018). SPE-190406-MS A Novel Ultra-Low IFT Spontaneous Emulsification System for Enhanced Oil Recovery in Low Permeability Reservoirs. http://onepetro.org/SPEOGWA/proceedings-pdf/18OGWA/2-18OGWA/D021S015R004/1239380/spe-190406-ms.pdf

[13] Rudnick, L. R. (2009). Lubricant Additives Chemistry and Applications Second Edition. CRC Press USA .

[14] Nengkoda, A. (2012). The Impact of TAN From Heavy Oil EOR to Operation and Integrity: Case Study. http://onepetro.org/SPEPOCE/proceedings-pdf/12POCE/All-12POCE/SPE-157440-MS/1657161/spe-157440-ms.pdf

[15] Pool, D., & Alberta Pitts, L. (2004). SPE 89386 Alkaline-Polymer Flooding of the. http://onepetro.org/SPEIOR/proceedings-pdf/04IOR/All-04IOR/SPE-89386-MS/1861378/spe-89386-ms.pdf

[16] Pawlak, Z. (2003). TRIBOCHEMISTRY OF LUBRICANT OILS. University of Technology and Agriculture Bydgoszcz. ELSEVIER BV Netherlands.

[17] Wassmuth, F. R., Green, K., Hodgins, L., & Turta, A. T. (n.d.). Polymer Flood Technology for Heavy Oil Recovery. http://onepetro.org/PETSOCCIPC/proceedings-pdf/07CIPC/All-07CIPC/PETSOC-2007-182/1834456/petsoc-2007-182.pdf

[18] Xu, D., Meng, Z., Zhou, Q., Li, Z., Lu, Y., Wu, H., & Hou, J. (2018). 2 SPE-192113-MS. http://onepetro.org/SPEAPOG/proceedings-pdf/18APOG/1-18APOG/D011S004R003/1221917/spe-192113-ms.pdf

The Effect of Adding Nickel Processing Tailings to Concrete Mixtures on a Laboratory Scale

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ABSTRACT

One of the stages in mining is processing. At the processing stage. minerals are processed to produce products with higher mineral concentrations. This process has by-products called tailings. The Indonesian mining industry as one of the world's nickel producers cannot be separated from this issue. The large nickel production also has an impact on the large tailings production. These tailings are generally just stockpiled without further use. This study aims to provide an understanding of the strength of the material resulting from the addition of tailings to the concrete mixture. Five variations of the material were made by mixing tailings with ratios of 0%, 20%, 40%, 50%, and 60% in the concrete mix. Physical and mechanical properties testing was carried out to obtain the rock strength value from the concrete sample. During this research, the parameters of UCS, Young's Modulus, and Poisson's Ratio were used as indicators of rock strength. Based on the tests that have been carried out, the addition of tailings to the concrete mix generally weakens the strength of the concrete. However, there is a trend of increasing rock strength at a mixture ratio of 60% where the UCS value is 1.324 MPa and Young's modulus is 0.584. Furthermore, porosity and degree of saturation are considered to have a role in these rock strength parameters. This is indicated by the degree of saturation of the 60% ratio, which is 18.8 with an increase in Young's Modulus and UCS. Based on these results, it can be concluded that tailings can be further utilized in concrete mixtures so that their availability in the field can be converted and reduced. Finally, other parameters of the mixing ratio can be performed to complement the weaknesses in this study.

CCS CONCEPTS

• **General and reference** → Document types; General conference proceedings.

KEYWORDS

Tailings utilization, concrete mixture, physical properties test, mechanical properties test, rock strength

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1 INTRODUCTION

Mining is a key sector in the growth of human society and has a significant impact on the economies of many nations worldwide. The importance of mining to society is hardly in dispute, and one of the minerals that is mined is nickel [1].

Nickel is one of the natural mineral resource commodities in the world, most of which are met by Indonesia. Based on the United States Geological Survey in the journal by Ade Kadarusman, June 2020, Indonesia is a country that has the largest nickel reserves in the world with a total of 4,346 million tons for 2020 [2]. Nickel is a valuable mineral that comes from the weathering of ultramafic rocks on the earth's surface. Nickel is used in a variety of commercial and industrial applications. Nickel ore found in Indonesia is nickel laterite, which if processed by the hydrometallurgical method or High-Pressure Acid Leaching (HPAL) will produce Nickel Sulfate and Cobalt Sulfate products. The two processed products are the basic ingredients for making electric car batteries which are predicted to develop in the coming years. With this, nickel demand will increase to 822,000 tons of Ni in the 2019-2030F period [3] Nickel ore is mined using an open-pit mining system and generally uses the open cast method. The mined material will then go through a screening process using a grizzly screen to separate nickel ore from quarry rock. Nickel ore that passes the screening process is then transported to be processed in a hydrometallurgical processing plant to produce Nickel Sulfate and Cobalt Sulfate with one of the by-products, namely tailings in the form of slurry.

While quarry rock can be used for various needs based on its size. Quarry rock which is relatively large in size (which includes boulder) can be used as support material and/or embankment material in the disposal area [4]. Overburden material in nickel mining is generally stored in an area called a disposal area. This overburden material generally can easily turn into mud if it is continuously exposed to heavy rain. One of the problems that are often encountered at nickel mining sites is the escape of the overburden material in the form of mud between the retaining embankment material which is only a quarry boulder. Therefore, it is necessary to have a boulder adhesive or embankment material that is more compact/tight. From a total of 8.3 million WMT/year, 66,335,000 tons/year of slurry will be produced [3]. Nickel ore processing tailings in the form of slurry are usually considered waste, worthless, and must be disposed of.

Tailings is a processing waste of minerals which has always been a complicated problem, namely regarding the location of waste disposal and its impact on the surrounding environment. To overcome this problem, the existing tailings must be utilized. After testing to find out what components are in the tailings, it is found that several tailings' components are almost similar to the cement components [5], [6]. Due to the large number of tailings produced and in order to reduce the amount of waste that must be disposed of into nature, this research will conduct a study on one solution to the utilization of the tailings. In the end, this study provides an understanding of the strength of the concrete mix material with tailings for further utilization.

2 METHOD.

2.1 Standard Concrete Mix

The standard concrete composition used in this study is based on SNI 7394-2008 concerning Procedures for Calculation of the Unit Price of Concrete Works for Building and Housing Construction which is also used as a reference in the Planning Criteria for the Building Parameters Section (KP – 06 of 2009 by the Ministry of Public Works, Directorate General Water Resources) for concrete-based dams [7], [8]. The standard concrete composition per 1 m3 according to SNI 7394-2008 can be seen in Table 1. Considering the capability of the equipment used, from the standard composition of concrete based on the various qualities above, what is used in this study is the standard composition of concrete with a quality of 12.2 MPa.

2.2 Sample Requirement

There are 5 variations in the percentage of tailings weight used in this study, namely 0%, 20%, 40%, 50%, and 60%. To calculate the material requirements to make a concrete mixture, it is necessary to calculate the volume of the required sample by calculating the volume of each sample from each test and then adding it up. The total volume of samples required is presented in Table 2.

2.3 Composition of Concrete Mix with Tailings

Based on the standard concrete composition for concrete quality of 12.2 MPa as shown in Table 1 and adjusted to the variation in the percentage of tailings weight, then for 1 m3 the composition of the concrete mixture is described in more detail in Table 3.

The material of the concrete mixture that is replaced with tailings is cement [9] So, by multiplying the required volume according to Table 2 with the composition of the concrete mixture in each sample variation (variation in the percentage of tailings weight to cement weight, namely 0%, 20%, 40%, 50%, and 60%) in Table 3, we get the composition of the concrete mixture new of each required volume. This composition is described in more detail in Table 4.

2.4 Physical Properties

The physical properties of rocks naturally vary according to the geological processes of formation, as well as subsequent processes after these rocks are formed. The physical properties of rock consist of bulk density in natural (γ_{nat}), dry (γ_{dry}), and saturated (γ_{sat}) conditions, apparent specific gravity (P_{app}), saturated water content (W_{sat}), natural water content (W_{nat}), degree of saturation (D_{sat}), and porosity (n). Physical properties test needs to be done, because the physical properties of the rock affect the mechanical properties of the rock [10], [11]. In the physical properties test, after getting the sample weight in natural (Wn), saturated (Ww), dry (Wo), and hanging (Ws) conditions, we can find out the values for the physical properties with the following equations (1-8). Physical properties testing was carried out in the rock mechanics laboratory of the Trisakti University mining engineering study program which can be seen in Figure 1. The duration of the test was 3 days to obtain weight data in natural, saturated, and dry conditions [11].

$$\gamma_{nat} = \left[\frac{W_n}{W_w - W_s}\right] \tag{1}$$

$$\gamma_{dry} = \left[\frac{W_o}{W_w - W_s}\right] \tag{2}$$

$$\gamma_{sat} = \left[\frac{W_w}{W_w - W_s}\right] \tag{3}$$

$$P_{app} = \left[\frac{W_o}{W_o - W_s}\right] \tag{4}$$

Table 1: Standard Concrete Mix 1 m^3 [7]

Quality (f'c) / Compressive Stress (Mpa)	w/c	Composition Material Based on Weight Conversion			
		PC(kg)	Sand (kg)	Gravel (kg)	Water (Liter)
7,4	0,87	247	869	999	215
9,8	0,78	276	828	1012	215
12,2	**0,72**	**299**	**799**	**1017**	**215**
14,5	0,66	326	760	1029	215
16,9	0,61	352	731	1031	215
19,3	0,58	371	698	1047	215
21,7	0,56	384	692	1039	215
24,0	0,53	406	684	1026	215
26,4	0,52	413	681	1021	215
28,8	0,49	439	670	1006	215
31,2	0,48	448	667	1000	215

[a] Explanation: w/c = water per concrete ratio dan PC = cement.

Table 2: Volume of Sample Requirement

Quality of Concrete 12,2 MPa		
Tailings Presentation	**Concrete Requirement Volume (mm^3)**	**Concrete Requirement Volume (m^3)**
0%	2062028.571	0.00206
20%	1855825.714	0.00185
40%	1855825.714	0.00185
50%	8248114.286	0.00824
60%	1670625	0.00167
Total:	15692419.29	0.01569

(a) (b) (c)

Figure 1: Physical properties test equipment; (a) digital scales; (b) Oven; (c) Desiccator.

$$W_{sat} = \left[\frac{W_w - W_o}{W_o}\right] x\ 100\% \quad (5)$$

$$W_{nat} = \left[\frac{W_n - W_o}{W_o}\right] x\ 100\% \quad (6)$$

$$D_{sat} = \left[\frac{W_w - W_o}{W_o}\right] x\ 100\% \quad (7)$$

$$n = \left[\frac{W_w - W_o}{W_w - W_s}\right] x\ 100\% \quad (8)$$

2.5 Mechancical Properties

The mechanical properties of rocks indicate the behavior of rocks when they are subjected to a force. Mechanical properties also show the strength of the rock through the magnitude of the force experienced by given to the rock at the point of failure (rupture point) [12]. In general, the mechanical properties are divided into compressive strength, tensile strength, and shear strength. The mechanical properties of rocks are influenced by their physical properties so that there is no special value for certain rock types. Therefore, laboratory testing is needed to determine the value of the mechanical properties of a rock [6], [13].

2.6 Uniaxial Compressive Strength

Uniaxial compressive strength (UCS) is the maximum compressive force that a rock can withstand under unconfined compression conditions. During sample testing, the force (F) is applied axially to the area of sample (A), while the lateral pressure is not controlled, and the deformation of the length (Δl) and the diameter (Δd) of the sample is not limited [10], [11]. In Figure 2. the test is carried out using the Automatic Compression Testing Machine, MATEST Servo Plus and assembled compressive strength testing equipment. The uniaxial compressive strength (σ_c) of the sample can be calculated at the point of failure using equation (9). While the axial (ε_A), lateral ($\varepsilon_D/\varepsilon_L$), and volumetric strains (ε_{vol}) can be calculated using equation (12-14) by comparing the dimensions of the initial length (l_o) and diameter (d_o).

$$\sigma_c = \frac{F}{A} \quad (9)$$

$$\varepsilon_A = \frac{\Delta l}{l_o} \quad (12)$$

$$\varepsilon_D = \varepsilon_L = \frac{\Delta d}{d_o} \quad (13)$$

$$\varepsilon_{vol} = \varepsilon_A + 2.\varepsilon_L \quad (14)$$

Poisson's ratio (υ) is the ratio between axial strain and lateral strain which can be obtained using equation (15). One of the parameters used to express rock strength is Young's modulus (E). Young's modulus is used to describe the elasticity of a rock [11].

Table 3: Composition of Concrete Mix per 1 m^3

Tailings Presentation	Quality of Concrete 12,2 MPa				
	Composition Material Based on Weight Conversion				
	PC (kg)	Sand (kg)	Gravel (kg)	Water (Liter)	Tailing (kg)
0%	299	799	1017	215	0
20%	239.2	799	1017	215	59.8
40%	179.4	799	1017	215	119.6
50%	149.5	799	1017	215	149.5
60%	119.6	799	1017	215	179.4

Table 4: Composition of Concrete Mixtures for Total Volume Requirements

Tailings Presentation	Volume (m^3)	Quality of Concrete 12,2 MPa				
		Composition Material Based on Weight Conversion				
		PC (kg)	Sand (kg)	Gravel (kg)	Water (Liter)	Tailing (kg)
0%	0.01569	4.692	12.538	15.959	3.374	0.000
20%	0.01569	3.754	12.538	15.959	3.374	0.938
40%	0.01569	2.815	12.538	15.959	3.374	1.877
50%	0.01569	2.346	12.538	15.959	3.374	2.346
60%	0.01569	1.877	12.538	15.959	3.374	2.815
Total:	0.07846	15.484	62.691	79.796	16.869	7.976

(a) (b)

Figure 2: Compressive strength testing equipment: (a) Automatic Compression Testing Machine, MATEST Servo Plus; (b) Assembled testing equipment.

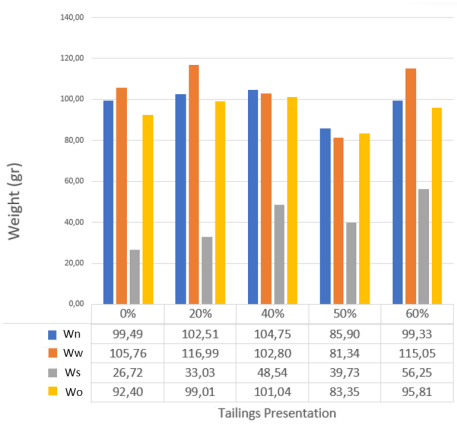


Figure 3: Tailings weight percentage – sample weight

Poisson's Ratio and Young's Modulus are two important parameters in determining rock behavior through equation (16).

$$v = \frac{\Delta\varepsilon_A}{\Delta\varepsilon_L} \tag{15}$$

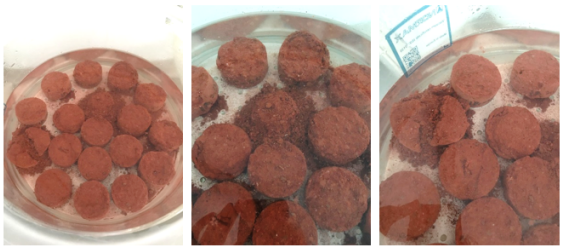
$$E = \frac{\Delta\sigma}{\Delta\varepsilon A} \tag{16}$$

3 RESULTS

3.1 Physical Properties Test Results

All variations of the sample the natural weight is relatively the same, this is due to the relatively similar size that it can be seen in Figure 3. Likewise, the dry weight increase and decrease in each composition was quite stable except for the 50% sample, this was because the 50% sample turned out to be after drying and cutting, it looked like a lot of cavities, unlike other samples. This also affects the saturation weight and hanging weight, because when the samples were soaked for 24 hours, some samples experienced dissolution in some parts which can be seen in Figure 4. The saturation and hanging weight of the 50% sample decreased quite dramatically when compared to other sample variations.

Figure 5 shows that the greater the percentage of tailings weight in the sample, the greater the weight of the contents. The value of the weight of the original content is an important value from the results of this physical property test. because the original fill weight value determines the strength of the material.



(a) (b) (c)

Figure 4: Condition of sample with tailings mixture when soaked.

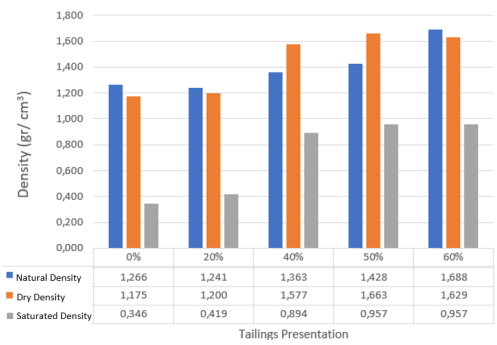


Figure 5: Tailings weight percentage - sample density.

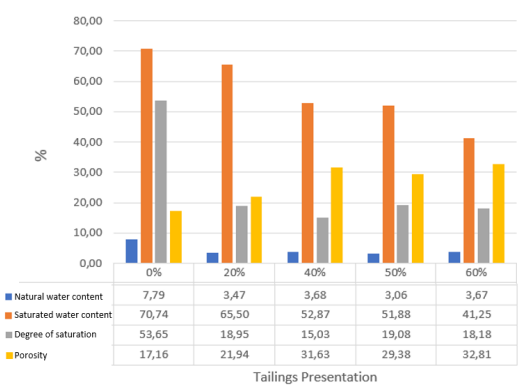


Figure 6: Tailings weight percentage - Moisture content - Saturation degree - Sample porosity.

In Figure 6, it can be seen that the sample with the least percentage of tailings, 0%, has the water content in the original or saturated condition and the highest degree of saturation. While the highest porosity value is owned by the 60% sample. This means that the greater the number of tailings in the concrete mixture, the larger the sample pores.

3.2 Uniaxial Compressive Strength Results

The value of the uniaxial compressive strength for the sample containing tailings fell quite far from the sample without tailings In

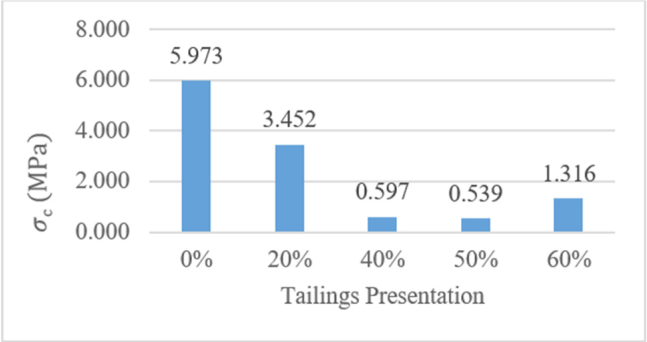


Figure 7: Uniaxial compressive strength test results (σ_c).

Figure 8: Uniaxial compressive strength test with assembly tool.

Figure 7. Even though the uniaxial compressive strength value in the 60% sample had increased compared to the 50% uniaxial compressive strength value in the sample, it was still not as strong as the 20% sample or even 0%. This proves that the addition of tailings to the concrete mixture is proven to weaken the uniaxial compressive strength of the pure concrete sample. Compared to all sample variations, the 20% sample has the highest uniaxial compressive strength value.

So that the percentage of tailings weight that is still possible to be utilized is in the range of 0 to 20%. samples that have a tailings presentation of 0%, were tested using compressive strength automation. However, samples mixed with tailings were tested using an assembly tool because the sample was relatively weak and the assembly tool had a smaller scale. This can be seen in the Figure 8.

Likewise, the value of Young's modulus, the more tailings used, the lower the Young's modulus. The more tailings used in the concrete mix; the lower the Young's modulus will be. This value also increased up to 60% of the Young's modulus value increased compared to the 50% sample, but still not greater than the Young's

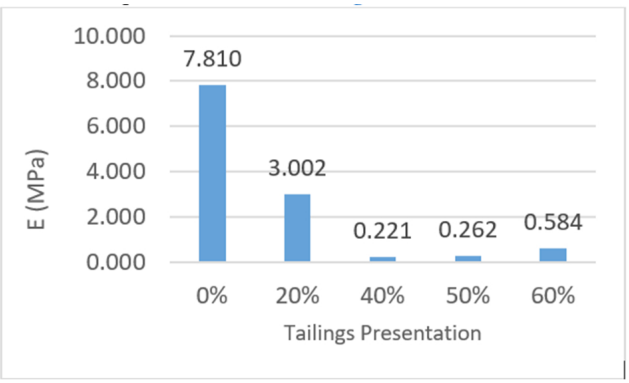


Figure 9: Measurement of Young's Modulus (E) on various samples

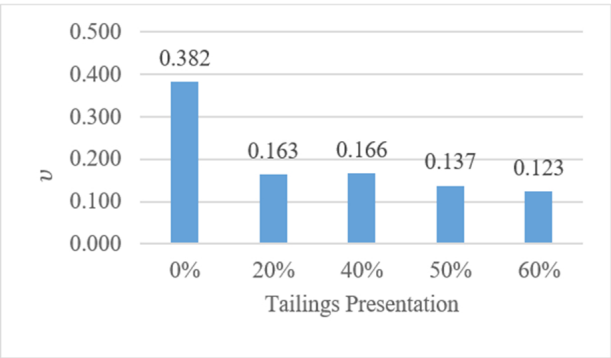


Figure 10: Poisson's ratio measurement results to the sample.

modulus value of the 0% and 20% samples. This is shown in Figure 9.

The decrease in value along with the addition of tailings to the concrete mixture also occurs in the Poisson ratio. Although not as drastic as the decrease in the value of uniaxial compressive strength and Young's modulus, it is proven that the addition of tailings to the concrete mixture also reduces the Poisson's ratio. This is shown by Figure 10.

3.3 Advanced Utilization Plans

The study that will be carried out is related to the effect of adding nickel processing tailings on the strength of the concrete mix and analyzing the effect of using the characteristics of the tested concrete mixture as embankment material in the disposal area. Tests of physical properties and compressive strength that have been carried out in the laboratory will be one of the variables needed to analyze the use of the criteria for the concrete sample as an embankment in the disposal area using the finite element method [12]. This is done as an effort to deal with tailings, reduce environmental pollution by reducing the addition of foreign materials at the mining site, and reduce the cost of making embankments. It is hoped that the use of tailings can also increase the strength of the embankment in the disposal area.

4 CONCLUSION

The presence of tailings from nickel ore processing creates new problems for the mining industry. most of the mining is used for these tailings stockpiling. a new approach to utilize nickel tailings so that tailings as a by-product can be further utilized and the resulting area impact can be reduced

This research is basic research that aims to determine the strength of the mixture of concrete with nickel. In the end, strong alloy materials can be used for many things mining and civil construction. Based on the research that has been carried out, it can be concluded that the more tailings addition to the concrete mixture has no significant effect on the weight of the concrete, increasing the value of bulk density, lowering the water content, lowering the degree of saturation, increasing the value of porosity, and increasing the value of the cavity ratio. However, the response shown is different on the mechanical properties of the material. The addition of tailings into the concrete mixture reduces the value of uniaxial compressive strength (UCS), lowers the value of Young's modulus, and lowers the value of Poisson's ratio.

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REFERENCES

[1] M. Gou, L. Zhou, and N. W. Y. Then, "Utilization of tailings in cement and concrete: A review," Science and Engineering of Composite Materials, 2019, doi: 10.1515/secm-2019-0029.
[2] Badan Geologi, "Laporan Kinerja Badan Geologi 2020," 2020.
[3] T. Gultom and A. Sianipar, "High pressure acid leaching: a newly introduced technology in Indonesia," IOP Conference Series: Earth and Environmental Science, 2020, doi: 10.1088/1755-1315/413/1/012015.
[4] X. Zhang, W. Li, L. Chen, and Y. Sun, "Extraction of open-pit mining area based on optimal scales selection and hierarchical classification: A case of Nonoc lateritic nickel," IOP Conference Series: Earth and Environmental Science, 2021, doi: 10.1088/1755-1315/865/1/012050.
[5] R. E. Pandeleke, "Kajian Manfaat Tailing untuk Bahan Bangunan Kontruksi," TEKNO/Volume07/No.52/April, 2010, doi: null.
[6] I. J. R. Sondakh, M. D. J. Sumajouw, R. Pandaleke, and S. O. Dapas, "Pemanfaatan Tailing Sebagai Subtitusi Parsial pada Semen Ditinjau Terhadap Kuat Tekan dan Kuat Trik Lentur (Studi Kasus: Tailing dari Ratatotok, Minahasa Tenggara)," Jurnal Sipil Statik Vol.3 No.4 April, 2015.
[7] Badan Standarisasi Nasional, "Standar Nasional Indonesia 7394-2008: Tata Cara Perhitungan Harga Satuan Pekerjaan Beton untuk Konstruksi Bangunan Gedung dan Perumahan," 2008.
[8] K. Perencanaan Bagian Parameter Bangunan, "Kementerian Pekerjaan Umum Direktorat Jendral Sumber Daya Air Direktorat Irigasi dan Rawa Standar Perencanaan Irigasi," 2013.
[9] A. Peys *et al.*, "Transformation of mine tailings into cement-bound aggregates for use in concrete by granulation in a high intensity mixer," Journal of Cleaner Production, 2022, doi: 10.1016/j.jclepro.2022.132989.
[10] [American Society fot Testing and Materials, "Designation: D 5731 – 07 Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications 1," 2007.
[11] International Society for Rock Mechanics and Rock Engineering, The ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 2007-2014. Springer International Publishing, 2015. doi: 10.1007/978-3-319-07713-0.
[12] A. D. Tzenkov, "Stability Analysis of a Tailings Dam: Existing State and Planned Heightening," https://scholarsmine.mst.edu/icchge/6icchge/session02/50, 2008.
[13] G. Rong, G. Liu, G. Liu, D. Hou, and C. Zhou, "Effect of particle shape on mechanical behaviors of rocks: a numerical study using clumped particle model.," The Scientific World Journal, 2013, doi: 10.1155/2013/589215.

Wind Speed Measurements and Comparisons in Cakung Jakarta

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ABSTRACT

Standard procedure to find the highest wind speed in an office area is defined, exercised and verified. Different tools are used in the procedure to find and measure wind speed at different locations starting from already available wind speed data at the Global Wind Atlas, then verified with a handheld anemometer and with a weather station. Wind data collections using handheld anemometer and weather station were done at 2-meter elevation and compared with the lowest elevation data available in the Global Wind Atlas at 10-meter height.

This procedure is applied in West Cakung Office area which is in an industrial complex in East of Jakarta. This project can contribute to other companies in the industrial complex to develop wind energy projects.

We found that the wind speed average from the Global Wind Atlas at 10-meter elevation, 1.43 m/s, higher than any measurements done at 2-meter elevation in several spots using handheld anemometer and weather station, 0.5 - 1.4 m/s. The measurement results using handheld anemometer is consistent with using weather station. The highest wind speed at 2-meter elevation occurs at a site located between two large buildings which create tunneling effect and amplify the wind speed. This site has higher wind speed even compared to the site 2-meter on the roof of buildings due to obstacles from walls and other structures on the roof.

Wind speed measurements using weather station was also done at higher elevation with the support of air balloon. The height of the air balloon is around 10 – 15 meter above the ground. We found that the wind speed average at this level is 1.6 m/s, which is slightly higher than the data from the Global Wind Atlas due to slightly higher elevation and maybe due to air acceleration around the balloon which has 1.5-meter diameter.

Although the wind speed average is consistent for all three sources: Global Wind Atlas, handheld anemometer, weather station, but the daily wind speed hourly index is not consistent. Wind speed data from the Global Wind Atlas shows that the peak of wind speed occurs in the morning time, while the data from handheld anemometer and weather station shows that the peak of wind speed occurs in the afternoon time. More investigations will be done to explain this inconsistency in the future work.

CCS CONCEPTS

• **Hardware**; • **Power and energy**; • **Energy generation and storage**; • **Renewable energy**;

KEYWORDS

wind speed, measurement, comparison, cakung, Global Wind Atlas, anemometer, weather station

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1 INTRODUCTION

Electrical energy can be regarded as the primary need of every human being in every sector starting from the industrial sector, transportation, households, power plants, public facilities, and so on. World Energy Outlook [1] shows that global demand for electrical energy is growing by 2.1% per year until 2040. This increase is expected to be very strong in developing countries, one of which is Indonesia. Based on data published by Perusahaan Listrik Negara (PLN) in 2021 [2], the main source of electrical energy in Indonesia is dominated by coal-fired steam power plants (PLTU) as much as 62.59% of the total electrical energy produced. Considering that coal is a non-renewable energy, it is necessary to prepare for the transition to renewable energy.

The Ministry of Energy and Mineral Resources (ESDM) has noted that the achievement of the New Renewable Energy (NRE) mix in 2021 has only been realized at 11.5% [3]. The Government of Indonesia has targeted the NRE mix of 23% in 2025 and 31% in 2050. As a form of the government of Indonesia's seriousness in developing NRE, the government formed a regulation in "Peraturan Pemerintah Nomor 79 tentang Kebijakan Energi Nasional pada Pasal 22 Ayat 1" states that the government and local governments provide fiscal and non-fiscal incentives to encourage diversification

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of energy sources and the development of renewable energy. All support for NRE development is based on the achievement of the Sustainable Development Goals (SDGs), especially point number seven on clean and sustainable energy. Therefore, this is a challenge for the government of Indonesia to encourage the development of each NRE that is effective and efficient with supporting factors in Indonesia so it can achieve the specified target.

Wind turbines or Wind Power Plants (PLTB) are one of the implementations of NRE to produce electrical energy with the principle of changing the kinetic energy of the wind then mechanical energy and finally into electrical energy through the rotation of the generator. The advantages possessed by PLTB include relatively low operational costs and do not require large areas of land such as Solar Power Plants (PLTS). Until 2021, only 131 MW of PLTB have been installed, or 0.2% of the energy mix in Indonesia [4]. Meanwhile, the target capacity in 2025 is 255 MW or 7.7% of the energy mix in Indonesia. This is because Indonesia is located on the equator where the wind speed often turns and is not constant. Therefore, Indonesia has not worked optimally on the development of PLTB as a massive producer of electrical energy. The development of PLTB in Indonesia is still challenging and different design of Vertical Axis Wind Turbine for the application in Indonesia has been studied in Refs. [5, 6].

An accurate survey of wind energy potential locations throughout Indonesia is very necessary as the first step in identification, selection of the appropriate type of turbine, and selection of PLTB installation locations. It can provide information about wind characteristics in various regions such as average, maximum, and minimum wind speed. Measurement of wind speed has been done, namely tracing the value of wind speed in the building area in Bandar Lampung and the average yield obtained is around 1.56 m/s [7]. Similarly, study of available wind speed in the south coastal area of Gorontalo Regency has been done in [8] and the highest average wind speed was around 4.2 m/s. Wind farm design for Oelbubuk in East Nusa Tenggara has been studied in [9] and they found yearly average wind speed of 7.3 m/s at 50-meter elevation. Measurements of wind speed in different locations were also done in Refs. [10][11][12][13][14][15].

In this EBT research projects, we are tracking wind characteristics data in Cakung office area to find out the most optimum locations. This aims to obtain the best method for wind speed data collection, especially about the characteristics of the wind source as one of the main factors determines before installing a wind turbine as an electricity generator. Several methods will be considered and compared, such as Wind Speed data collection from the Global Wind Atlas website, wind speed measurement using a handheld anemometer, wind speed measurement using a weather station, and higher altitude measurement supported by air balloon.

2 RESEARCH METHODOLOGY

2.1 Global Wind Atlas

The easiest data collection of wind speed is from the Global Wind Atlas website [16]. This website can provide maps of wind speed distribution in almost everywhere on the Earth. In example, Global Wind Atlas can show wind speed distribution in the Java island at the elevation of 10 meters above the ground as shown in Fig. 1.

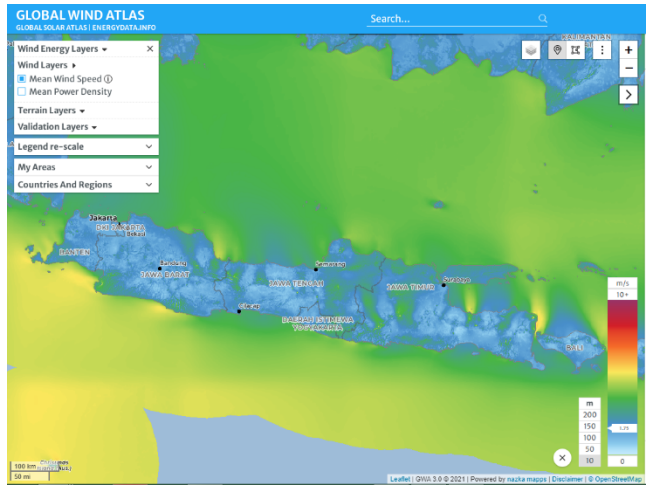

Figure 1: Wind Speed Distribution at The Elevation Of 10-Meter Above the Ground in Java Island from The Global Wind Atlas

Figure 2: Simple Handheld Anemometer.

Notice that the wind speed in most of the java area is quite low, around 1.5 m/s with some local areas with higher wind speed.

Wind data at different elevation are available in the Global Wind Atlas, at 10, 50, 100, 150 and 200 meter above the ground. This is suitable for different wind turbine tower heights. The lowest elevation is 10 meter which is higher than most obstacles on the ground, such as houses, fences and trees.

2.2 Handheld Anemometer

To support the initial data, wind speed data was collected in a conventional way, namely using a handheld anemometer at several locations. Data retrieval is carried out with different time variations during working hours, from 8:00 to 16:00 o'clock with a span of one hour. The handheld anemometer used in this project is shown in Fig. 2. This tool can measure not only wind speed, but also air temperature. To measure the wind speed properly, the blades need to be directed along with the wind direction. To do that, simply by rotating around the tool until the highest wind speed measurement is found.

Figure 3: Weather Station Consists of Outdoor Sensors and Indoor Monitor. Outdoor Sensors Are Supported By 2-Meter Pole with Cemented Bucket.

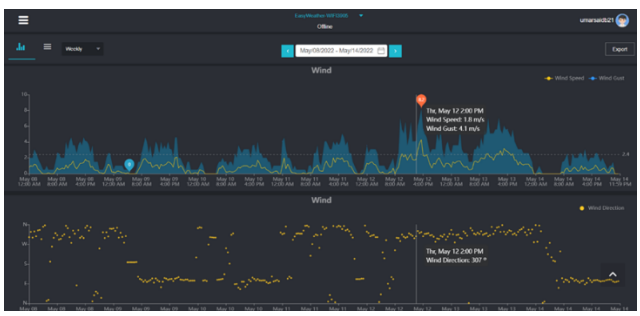

Figure 4: Display from ecowitt.net Website to Show Wind Data from The Weather Station.

2.3 Weather Station

Wind speed data retrieval is also done using a weather station at several locations in the Cakung office area at the elevation of 2-meter from the ground. Real-time data will be visible on a monitor with integrated Wi-Fi and can be monitored on the website and application as well. Wind speed data retrieval is carried out for approximately one week at each location. The monitor must be connected to electrical power and also connected to Wi-Fi continuously for data sending everytime to be recorded on the website and application. The maximum distance between the monitor and the weather station is 100 meters. The weather station configuration is shown in Fig. 3

Data will be monitored through the website at ecowitt.net and available to be downloaded in the form of an Excel document. The front page displayed on the website is in the form of a graphic as shown in Fig. 4. Not only the wind speed recorded at the weather station but also wind gust. A wind gust is a sudden, brief increase in the speed of the wind followed by a lull, usually less than 20 seconds. However, wind gust is not a parameter that is used as a wind energy indicator but for a construction consideration parameter of a wind turbine.

Wind speed data collection is carried out for one to two weeks whose overall data is averaged based on the hour and day. The weather station outdoor sensors are mounted on 2-meter pole that

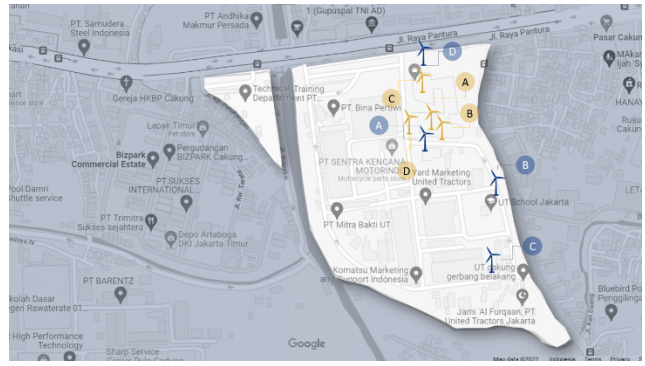

Figure 5: Eight Locations of The Weather Station in Cakung Office Area for Wind Speed Measurements.

Figure 6: Air Balloon With 3 Anchoring Ropes for Position Stability. Weather Station Outdoor Sensors Are Hung to The Air Balloon.

is given a dry cement in container with a mass of approximately 70 kg so the support is sturdy and does not fall easily but still moveable. There are 8 locations of weather station to retrieve wind data around the Cakung office area as shown in Fig. 5

2.4 Air Balloon

It is necessary to retrieve wind speed data at a higher altitude to avoid obstacles such as buildings and trees. Wind speed data retrieval for this elevation is carried out using air balloon for a week in the altitude about 10 to 15 meters in the Cakung office area as shown in Fig. 6. The air balloon has 1.5-meter diameter and it is made of PVC material. The PVC air balloon is durable in the air and quite thick, 0.17 mm so the gas inside the air balloon does not come out easily. The gas used is hydrogen because it has good lifting power, and also commonly used for outdoors. Although hydrogen is flammable, but as long as there is no contact with fire, it should be safe.

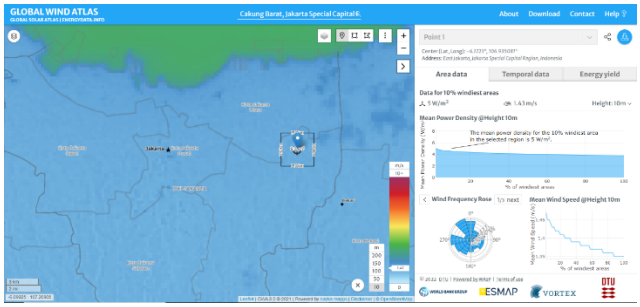

Figure 7: Wind Speed Distribution at The Elevation Of 10-Meter Above the Ground in West Cakung Area.

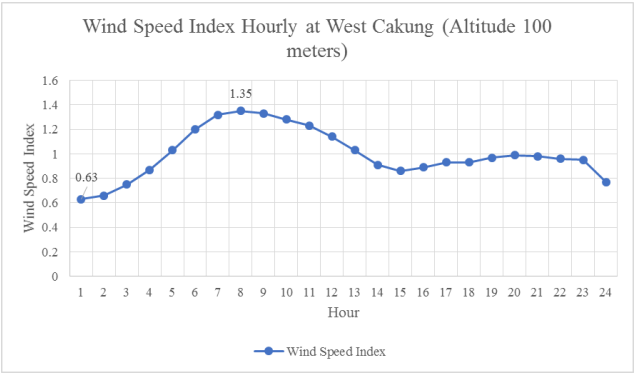

Figure 8: Wind Speed Index as A Function of Time at The Elevation Of 100-Meter Above the Ground in West Cakung Area.

3 RESULT AND ANALYSIS

3.1 Global Wind Atlas

Wind speed data in the Cakung office area, which is part of West Cakung region at 10-meter elevation from the Global Wind Atlas is shown in Fig. 7. The average wind speed was recorded at around 1.43 m/s.

The wind speed will not always be the same at each hour. According to the Global Wind Atlas, the West Cakung area recorded the highest wind speed index at 8:00 o'clock with a value of 1.35 and the lowest wind speed index at 1:00 o'clock with a value of 0.63 as shown in Fig. 8. This index is a relative value to the wind speed average. Based on this graph, relatively higher wind speed would occur in the morning time, regular wind speed from afternoon time till just before the mid-night and low wind speed from mid-night until dawn.

The Global Wind Atlas also provides information on wind speed monthly variation for the whole year. This information is usually related to the seasons in the area. Wind Speed Index Monthly is shown in Fig. 9. Based on the graph, from the month of April until November, wind speed is less than average. Peak of wind speed occurs in the month of December and January.

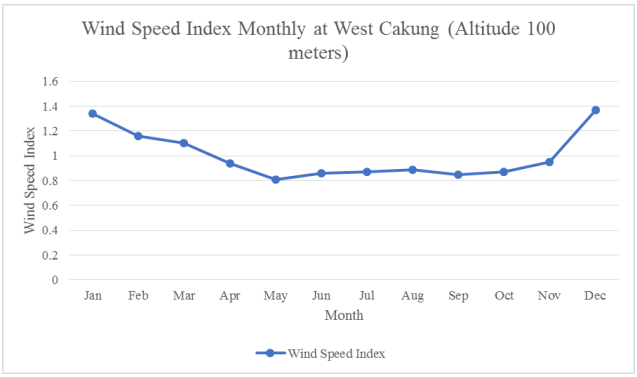

Figure 9: Wind Speed Index Monthly at The Elevation Of 100-Meter Above the Ground in West Cakung Area.

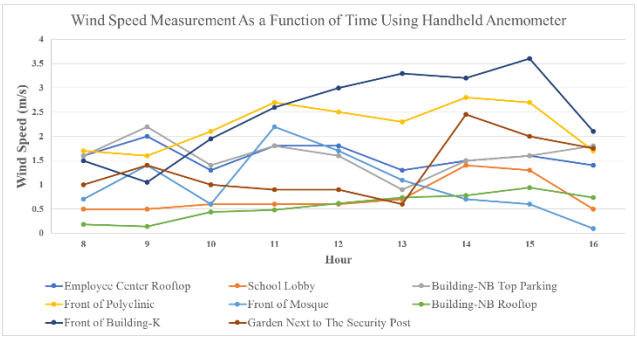

Figure 10: Wind Speed Measurements At 8 Locations as A Function of Time Using Handheld Anemometer.

3.2 Handheld Anemometer

The locations of wind speed data retrieval using the handheld anemometer are the same locations as the weather station. The results of wind speed data retrieval using the handheld anemometer are presented in Fig. 10. The graph shows that the highest wind speed curves are for the locations in front of Building-K and in front of Polyclinic. While in School lobby and Building-NB rooftop are the lowest curves in the graph because for those two locations, there are obstruction objects from several directions, especially blocked by buildings.

Based on the graph in Fig. 10, the peak of wind speed occurs in the afternoon time while the data from Global Wind Atlas in Fig. 8 shows that the peak of wind speed occurs in the morning. This means that the trend of wind speed hourly from the Global Wind Atlas does not match the data from the handheld anemometer.

3.3 Weather Station

The wind speed measurement results from the weather station are presented in Table 1 and in Fig. 11 and the results are similar to the data taken by the handheld anemometer.

The highest wind speed measurements are taken in front of Polyclinic and in front of Building-K, which have wind speed averages

Table 1: Wind Speed Average at 8 Locations Using Weather Station.

No	Location	Wind Speed Average (m/s)
1	Employee Center Rooftop	1.2
2	School Lobby	0.5
3	Building-NB Top Parking	1.2
4	Front of Polyclinic	1.4
5	Front of Mosque	0.6
6	Building-NB Rooftop	0.5
7	Front of Building-K	1.3
8	Garden Next to the Security Post	1.1

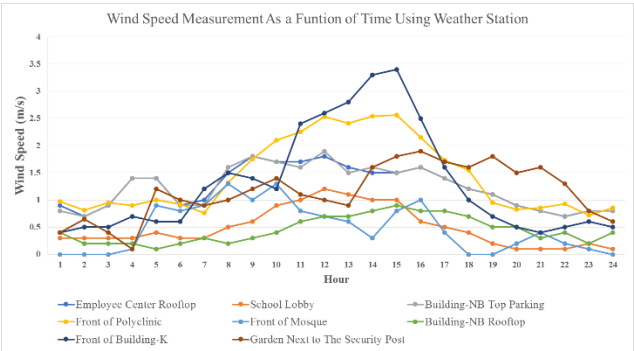

Figure 11: Wind Speed Measurements at 8 Locations as A Function of Time Using Weather Station.

Figure 12: Tunneling Effect Between Two Large Buildings Resulting Higher Wind Speed Measurements.

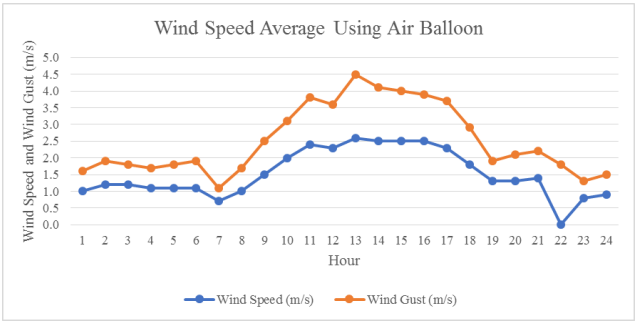

Figure 13: Wind Speed Measurements as A Function of Time Using Weather Station Hung To the Air Balloon.

of 1.4 and 1.3 m/s. While the lowest are taken in School lobby and Building-NB rooftop with wind speed average for both of 0.5 m/s.

The wind speed average from weather station measurements at 8 locations are similar to the data from the handheld anemometer. The weather station measurement data in Fig. 11 is quite comparable to the handheld anemometer measurement data in Fig. 10, that the peak of wind speed occurs in the afternoon time. However, both data are inconsistent with the wind speed index hourly from the Global Wind Atlas in Fig. 8

Comparing the results in Table 1 to the wind speed average from the Global Wind Atlas, 1.43 m/s, the averages at 8 different locations are less than the one from the Global Wind Atlas. This is to be expected because all data in the table are collected in elevation of 2-meter, which is less than the Global Wind Atlas data at elevation of 10-meter. However, we learned that in some conditions, wind speed average is higher at different locations than areas with a lot of blockages. As shown in Fig. 12, the site in front of Polyclinic is between two large buildings creating tunneling effect that can accumulate wind energy resulting higher wind speed average.

3.4 Air Balloon

Wind speed at altitude of 10 to 15 meters has a slightly higher average value, although it is not very significant. The wind speed measurement using air balloon as a function of time is shown in Fig. 13. The average value of wind speed (blue curve in Fig. 13) obtained in one week is 1.6 m/s. The value of the wind speed average obtained is still close to the wind speed average value recorded on the Global Wind Atlas, which is 1.43 m/s.

When this data compared to the wind speed index hourly in West Cakung recorded in the Global Wind Atlas, the profile value is inconsistent. This data is more consistent with the measurement data from the handheld anemometer and the weather station at 2-meter elevation.

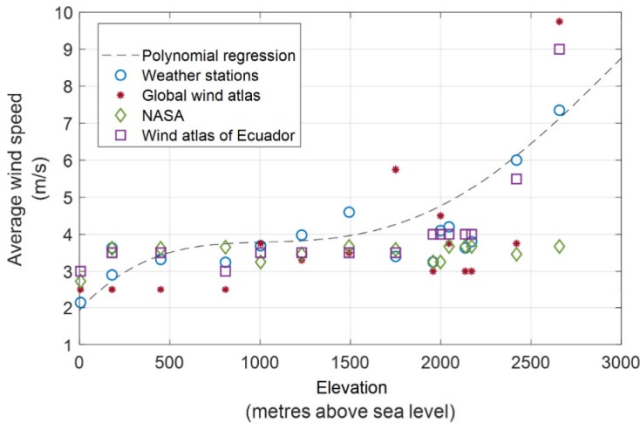

Figure 14: Average Wind Speed and Terrain Elevation Obtained from Weather Stations, Along with Other Data Sources for The Same Geographic Locations: Global Wind Atlas, NASA, And Wind Atlas of Ecuador. Source: Ref. [17].

Higher value of wind speed with increasing altitude has been studied in [17]. The paper showed that the wind speed is mainly a function of terrain elevation. Correlation of wind speed curve along with other data sources such as Weather stations, Global Wind Atlas and NASA is shown in Fig. 14. For the elevation range of 10 to 200 of our interest, the wind speed average curve in Fig. 14 shows that wind speed average is continuously going higher as the elevation going higher.

This justifies that the wind speed measurement using air balloon should be higher than using 2-meter elevation of weather station and handheld anemometer. The second reason is because at the altitude of 10 - 15 meter, there are fewer obstructions compared to the height of 2 meters. These obstructions will block the wind and reduces the wind speed.

4 CONCLUSION

The wind speed average at 10-meter elevation from Global Wind Atlas in Cakung office area is comparable to the data from handheld anemometer and weather station supported by 2-meter pole and by 10-15-meter elevation air balloon.

The daily wind speed index hourly from the Global Wind Atlas is not consistent with the data from handheld anemometer and weather station. The peak of wind speed from the Global Wind Atlas occurs in the morning time, while from handheld anemometer and weather station, the peak occurs in the afternoon time.

The highest wind speed average at 2-meter elevation from handheld anemometer and weather station measurements occurs in the front of Polyclinic and in front of Building-K with the value of 1.4 and 1.3 m/s. There is a tunneling effect happened at these two locations due their position between two large buildings.

The lowest wind speed average at 2-meter elevation occurs at the spots with large obstacles, such as trees, walls, buildings.

The wind speed average measured using air balloon is larger than any measurements done at 2-meter elevation. This follows the theory that wind speed average is higher at higher elevation.

ACKNOWLEDGMENTS

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REFERENCES

[1] International Energy Agency. 2019. World Energy Outlook. www.iea.org/topics/world-energy-outlook
[2] PLN. 2021. Statistik PLN 2021. https://web.pln.co.id/stakeholder/laporan-statistik
[3] Kementerian ESDM. 2021. Handbook of Energy & Economic Statistics of Indonesia. www.esdm.go.id/en/publication/handbook-of-energy-economic-statistics-of-indonesia-heesi
[4] Balai Besar Survei dan Pengujian Ketenagalistrikan, Energi Baru, Terbarukan, dan Konservasi Energi. 2022. Potensi Energi Angin Indonesia 2020. Esdm.go.id. https://p3tkebt.esdm.go.id/pilot-plan-project/energi_angin/potensi-energi-angin-indonesia-2020.
[5] Dena Hendriana, Eka Budiarto and Arko Djajadi. 2020. Experimental Simple Vertical Axis Wind Turbine for Low Wind Speed. In Proceedings of International Conference on Engineering and Information Technology for Sustainable Industry (ICONETSI 2020), September 28-29, 2020.
[6] Dena Hendriana, Eka Budiarto, Alexander Clements, Arko Djajadi. 2018. Design comparison of wind turbines for low wind speed, Proceedings of the International Conference on Innovation, Entrepreneurship and Technology, 30-31 October 2018.
[7] Pramono, Y., Warsito, & Syafriadi. 2016. Monitoring Data Kecepatan dan Arah Angin Secara Real Time Melalui Web. Jurnal Teori dan Aplikasi Fisika Vol. 04, No. 02, Juli 2016.
[8] Arthur Gani Koto. 2020. Study availability of wind speed in the south coastal area of Gorontalo Regency, Indonesia. Jurnal Sains Informasi Geografi Vol. 3 No. 2 November 2020.
[9] Herliyani Suharta, Sahat Pakpahan, Soeripno Martosaputro. 2011. Wind Farm design for Oelbubuk in East Nusa Tenggara, Indonesia. Journal of Informatics and Telecommunication Engineering JITE Vol. 1 No. 12, Februari 2011
[10] Firsta Zukhrufiana Setiawati, Rudi Kurnianto, Bomo Wibowo Sanjaya, Rudy Gianto, Seno Darmawan Panjaitan, Ananggirieza Nugraha. 2020. Performance of Wind Power Plant in West Kalimantan, Indonesia. Jurnal Edukasi dan Penelitian Informatika JEPIN Vol. 6 No. 3, Desember 2020.
[11] U.Z. Adlina, A. Ihwan, and Apriansyah. 2018. Potensi Energi Listrik Tenaga Angin di Kota Pontianak. Vol. VI (01), Prisma Fisika, 2018.
[12] K. E. Bawan. 2007. Kajian Potensi Energi Angin Kabupaten Kaimana Provinsi Papua Barat. Vol. 6 (2), Natural, 2007.
[13] A. Sam and D. Patabang. 2005. Studi Potensi Energi Angin di Kota Palu untuk Membangkitkan Energi Listrik. Vol. 3 (1), Jurnal SMARTek, 2005.
[14] Ryski. 2013. Kajian Kelayakan Potensi Energi Angin Pada Kawasan Universitas Tanjungpura Pontianak Untuk Dimanfaatkan Menjadi Energi Listrik. Jurnal Teknik Elektro Untan, Vol. 1, No.1, 2013.
[15] R. U. Irene, Muh. Ishak Jumarang, and Apriansyah. 2018. Perhitungan Potensi Energi Angin di Kalimantan Barat. Prisma Fisika, Vol. VI, No. 01, 2018.
[16] Global Wind Atlas. 2022. https://globalwindatlas.info/
[17] J.C. Solano. T. Montaño. J. Maldonado-Correa. A. Ordóñez, M. Pesantez. 2021. Correlation between the wind speed and the elevation to evaluate the wind potential in the southern region of Ecuador. 6th International Conference on Advances on Clean Energy Research, ICACER 2021 April 15–17, 2021, Barcelona, Spain

The effect of supporting facilities growth around the urban campus on land-use change

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ABSTRACT

Previous research revealed spatial interactions between several public facilities and campus locations. Therefore, it is likely that a campus development in a location will encourage the growth of various supporting facilities in that location. Thus, the question arises: Do the campus's existence and various public facilities around it encourage changes in land use in the area? The objective of this study is to explore land-use changes in the areas around education facilities. This study used a Geographical Information System (GIS) to process and analyze data, including the projection system setup, digitizing, editing, and visualizing. The results of the land use analysis for several consecutive years show a tendency to increase the built-up area category and decrease the cultivated land category. These findings provide insight into the questions underlying this research. These findings provide insight into the questions underlying this research and encourage further research on how to determine the appropriate location for developing various supporting facilities by understanding the environmental transformation of the existing urban campus. The relationship between campus locations and neighborhood characteristics, such as demographics and income, also requires further research.

CCS CONCEPTS

• **Information systems** → Information systems applications; Spatial-temporal systems; Geographic information systems.

KEYWORDS

Urban campus, Land-use, Geographical Information System, Facility location

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1 INTRODUCTION

Currently, online learning and MOOCs are essential issues in higher education, but Carlson emphasized that the physical location of the campus is still an essential element in education [1]. The academic community's mobility and activity will affect the urban communities, including providing public facilities. Education development facilities have contributed to the growth of urban areas, including encouraging environmental transformation [2].

The previous research identifies several facilities generally located around campus locations in the Greater Jakarta Area [3] and the interaction between facilities [4]. Other research shows that in the Greater Jakarta Area, there is a co-location rule between campus locations and fast-food restaurants, as well as interactions with other public facilities. The co-location rules are generated between footfall, health facilities, recreation/leisure facilities, politics/business offices, and entertainment facilities [5]. These findings correspond with Tobler's first law of geography, which states that "everything is related to everything else, but near things are more related than distant things" [6]. The socio-economic structure of the Greater Jakarta Area transformed from year to year to become more focused on urban activities, which affect spatial segregation [7].

Previous research revealed spatial interactions between several public facilities and campus locations. Therefore, it is likely that a campus development in a location will encourage the growth of various supporting facilities in that location. Thus, the question arises: Do the campus's existence and various public facilities around it encourage changes in land use in the area?

A search through the Scopus database with the keyword 'campus' yielded 9,148 documents. Adding the keyword 'land use' and only document type 'article' narrows the number of documents to 157. Table 1 and Figure 1 show the occurrence of keywords (the minimum occurrence threshold is five times) and the relationship between keywords that appear together in an article. Each cluster has a specific focus, such as the first cluster focusing on 'sustainability - land use - campus'; the second cluster focuses on 'university - mobility - transportation'; the third cluster focuses on 'student - human - perception'; and the fourth cluster focuses on 'spatial analysis'.

Visualization in VOSviewer shows all the networks between the keyword 'land use' and various other keywords, as seen in Figure 2, including words related to university-campus, mobility-transportation, and sustainability-planning. From the search results in the Scopus database, some studies discuss the effect of developing campus facilities and increasing campus life on urban changes that encourage land use changes [8],[9],[10].

Table 1: Land-Use Changes from 2014 to 2018

Cluster	Label	Weight Occurences
1	university sector; campus; urban planning; land use; sustainable development; campus planning; sustainable campus; campus sustainability; urban area; walking; gis; spatiotemporal analysis; biodiversity; higher education; walkability; urban design	Mean: 11.06 Range: 5 - 43
2	university campus; parking; bicycles; commuting; urban transport; population statistics; transportation; transportation mode; public transport; travel behavior; land use planning; mobility; sustainable mobility; university campuses	Mean: 9.86 Range: 5 - 56
3	student; students; sustainability; perception; university; human; universities; green campus; questionnaire survey; humans; accessibility; cities; developing world; greenspace	Mean: 10.21 Range: 5 - 21
4	surveys; spatial analysis; building; carbon emission; covid-19	Mean: 6.60 Range: 5 - 9

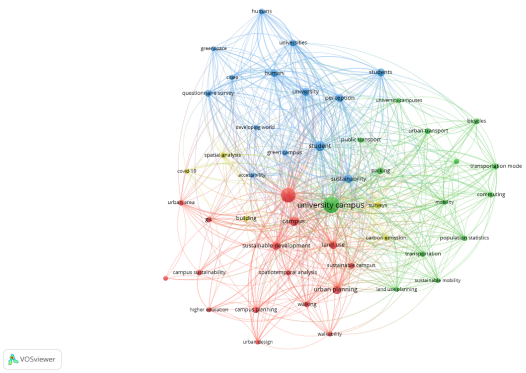

Figure 1: Co-occurrence Terms Network Visualization from VOSviewer (KEYWORD (campus)) AND ("land use")

The objective of this study is to explore the land-use changes in the areas around education facilities. This study used a Geographical Information System (GIS) to process and analyze data, including the projection system setup, digitizing, editing, and visualizing. This research resulted in insight for determining the appropriate location for developing various supporting facilities by understanding the environmental transformation of the existing urban campus.

2 DATA SOURCES AND METHODS

This research used spatial data to explore the land-use changes in the areas around education facilities, including area boundaries, a land-use map, and eight categories of public facilities locations (including universities). The Greater Jakarta Area is divided into ten regions: Central Jakarta, East Jakarta, North Jakarta, South Jakarta, West Jakarta, Bekasi, Bogor, Depok, Tangerang, and Thousand Island. This study analyzed the land-use map from 2014 to 2018. The land-use maps are reclassified into five categories: built-up area, cultivated land, forest land, unused land, and water area. The eight categories of public facilities include universities, schools, public transportation, green park, religious place, hospital, sports areas, and police stations. Previous research found that these public facilities support an area to become a livable area [11].

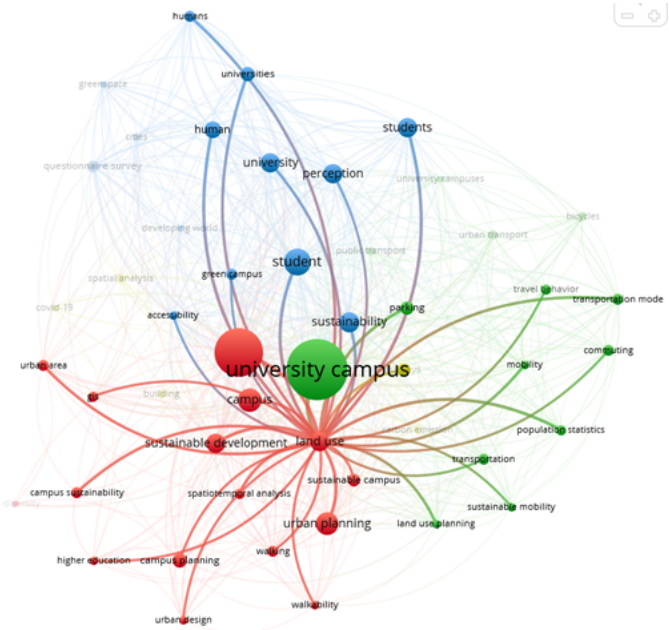

Figure 2: The Network Between "land use" with Other Keywords

This research used a Geographical Information System (GIS) for all spatial data management processes, starting from the projection system setup, digitizing, data editing, and data visualization, to the analysis process. All spatial data obtained from other sources are managed through the GIS interface. Some spatial data that cannot be obtained from other sources are digitized using existing tools. The spatial data from other sources have a WGS 84 geographic coordinate system. In contrast, the coordinate system is projected into meter units using the WGS 84 UTM Zone 48S projection system for the subsequent analysis.

After the data preparation process, mapping the distribution of the university's location and other public facilities continued. The grouping pattern in each category was visualized by making a KDE map (Kernel Density Estimation). Density estimation is used to gain a general understanding of specific data properties. Sometimes

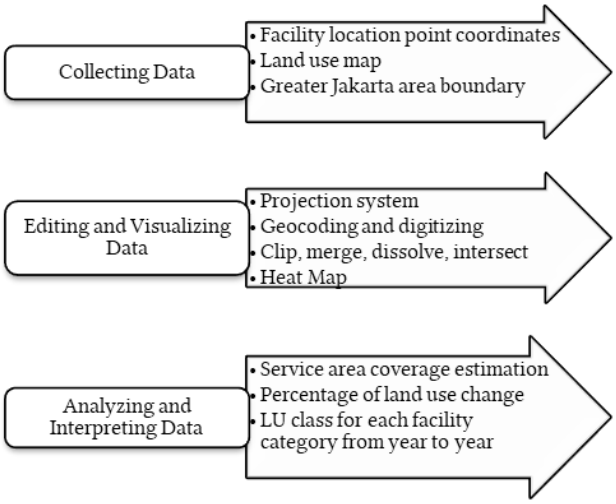

Figure 3: Research Method

the interpretation can be used to prove a conclusion, but in other cases, to get clues about what other data needs to be collected or what further analysis needs to conduct [12]. Density mapping with kernel estimation in this study was applied using the Heatmap plugin feature from QGIS software. The data used is the data point location of a feature whose distribution density is known.

Figure 3 shows the stages of research conducted in this study. The first stage is to collect data related to the research objectives. Spatial data for public facilities was obtained from OpenStreetMap, while data for administrative boundaries and land use maps were obtained from the government website.

Spatial data processed using QGIS software is then interpreted and further processed. The heatmap plugin from QGIS generates a kernel density map to estimate the service coverage area for campuses and services for seven other public facilities. The distribution of the spatial data is estimated using the KDE method, which determines the number of locations per feature per unit area using search radius parameters [13]. The search radius parameter is calculated using standard distance values from some spatial data in spatial point pattern analysis. KDE visualization in the form of a density raster shows whether the locations are randomly distributed without a particular pattern or have a tendency to cluster. Calculating land-use change for two consecutive years for each land-use category is carried out using the intersect function in QGIS. Further analysis was conducted by identifying land use categories for each public facility year.

3 RESULTS AND DISCUSSION

The KDE map is generated to visualize the eight distribution locations of public facilities, as shown in Figure 4. The KDE map shows locations with solid concentrations of facility distribution. The kernel estimate calculates the density at all locations resulting in a continuous surface with a darker color and tighter contours, indicating a higher density. Visual analysis can be performed to check the density variability of a public facility.

The KDE map in Figure 4 visualizes the uneven distribution for eight public facilities. These eight public facilities generally have different distribution patterns. The few similarities between these eight public facilities are that they are spread out, especially in the big cities of Jakarta. This follows the results of previous studies that the presence of public facilities around the campus indicates the existence of consumers or, in other words, the occurrence of public life [3],[4].

The distribution of public facility locations is concentrated in the Jakarta area as a metropolitan city. However, facilities have begun to spread to areas around Jakarta, especially facilities that are a daily necessity for the community, such as schools, transportation, and religious places. The highest school density, marked with the darkest colored symbols, has more than 50 schools for a given area. Meanwhile, the highest density for religious places consists of 38 facilities, and for transportation facilities, it consists of 141.

The development in the peripherals continues and is one-factor driving land-use changes. Currently, in the peripheral area of the big city, there is still a limited number of service facilities. However, along with urbanization and economic growth, there is potential growth in the availability of public facilities.

This study aims to obtain an initial description of land-use changes in Jakarta's metropolitan city and its vicinity. Land use maps in 2014, 2015, 2016, 2017, and 2018 show changes in land use for each category, as shown in Table 2. The land-use class conversion is identified using the tool from ArcGIS ("Intersect" function) and is calculated for each change in land area. The most significant changes occurred in the land-use class, built-up area, and cultivated land. The built-up area increased by 10.76% (increased by 23,559 ha from the previous 219,045 ha), while the cultivated land decreased by 5.61% (decreased by 21,287 ha from the previous 379,548 ha). This land-use change certainly needs strict surveillance from the authorized institution so that the land conversion process does not endanger ecosystem services.

Various studies have shown that changes in land use occur due to the increasing activity of urban communities. This occurs due to the use of land for infrastructure and various other buildings to meet the community's daily needs. Table 3 shows the land use class for each category of public facilities discussed in this study for each year based on 2014, 2015, 2016, 2017, and 2018 land use maps. The land use map is obtained from the Ministry of Environment and Forestry publication, which is an interpretation of satellite imagery. Meanwhile, the location of public facilities is obtained from the OpenStreetMap downloaded in 2020.

Through the GIS interface, the status of land use is identified. It was not a built-up area for several locations of public facilities (for each category) in previous years. They generally cultivated land that turned into a built-up area. Changes in land class into built-up areas for the eight categories occurred between 1% and 12%. This finding confirms that the growth in the number of public facilities to meet community needs encourages environmental transformation in general or specific results in changes in land use. From a business perspective, information about the spatial interaction between education facilities and other facilities can be considered in developing a service facility in a complex network of daily service activity interactions. This research can also provide input for the government in the decision-making process for general land use

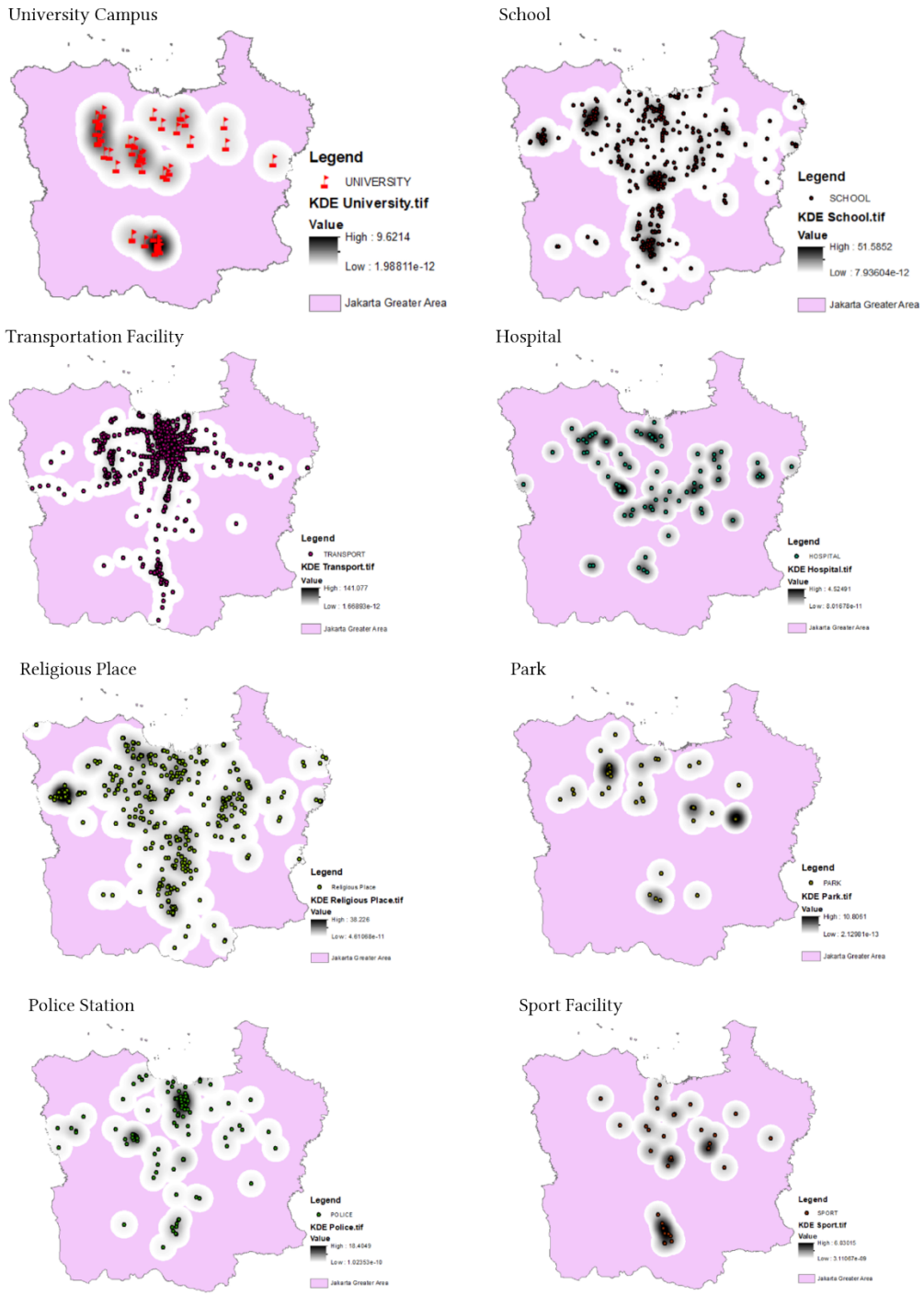

Figure 4: Kernel Density Estimation (KDE) Map Location Distribution of Public Facilities

planning and the development of public facilities so that they continue to monitor and evaluate their conformity with the Regional Spatial Plan.

4 CONCLUSION

This study aims to explore the land-use changes in the areas around education facilities. Based on previous research, this study examines seven public facilities that have spatial interactions with campus locations. The analysis shows that these public facilities encourage

Table 2: Land-Use Changes from 2014 to 2018

AREA (HA)	LU2015					
LU2014	Built-Up Area	Cultivated Land	Forest Land	Unused Land	Water Area	Grand Total
Built-Up Area	219042.43	3.02				219045.45
Cultivated Land	22.26	379525.41			0.20	379547.86
Forest Land	138.45	4330.31	56843.70		0.88	61313.34
Unused Land	6.03	9.94		2601.29		2617.25
Water Area					18142.51	18142.51
Grand Total	219209.16	383868.68	56843.70	2601.29	18143.58	680666.42
AREA (HA)	LU2016					
LU2015	Built-Up Area	Cultivated Land	Forest Land	Unused Land	Water Area	Grand Total
Built-Up Area	216917.07	2195.94	85.32	6.03	4.73	219209.09
Cultivated Land	7828.30	369891.47	4787.22	127.28	1234.35	383868.61
Forest Land	80.44	1097.05	55562.72	103.45		56843.67
Unused Land	18.72	226.36	598.50	1757.71		2601.29
Water Area	94.15	199.78	2308.38	1.97	15539.30	18143.58
Grand Total	224938.69	373610.60	63342.13	1996.44	16778.38	680666.24
AREA (HA)	LU2017					
LU2016	Built-Up Area	Cultivated Land	Forest Land	Unused Land	Water Area	Grand Total
Built-Up Area	222889.91	1505.25	80.44	366.10	97.07	224938.78
Cultivated Land	14047.42	356660.77	1286.90	798.67	816.90	373610.65
Forest Land	62.59	5099.64	55563.34	480.81	2135.84	63342.22
Unused Land	114.74	165.95	102.59	1597.49	15.67	1996.44
Water Area	2813.49				13964.90	16778.39
Grand Total	239928.14	363431.62	57033.27	3243.06	17030.38	680666.48
AREA (HA)	LU2018					
LU2017	Built-Up Area	Cultivated Land	Forest Land	Unused Land	Water Area	Grand Total
Built-Up Area	236849.32	288.28		0.00	2790.76	239928.36
Cultivated Land	5346.45	357686.89	50.31	284.24	63.92	363431.81
Forest Land	9.12	271.94	56663.20	89.00		57033.27
Unused Land	398.40			2844.66	0.00	3243.07
Water Area	1.53	13.41	0.00		17015.44	17030.38
Grand Total	242604.82	358260.51	56713.51	3217.91	19870.13	680666.88

Table 3: Built-Up Area Land-Use Class of Public Facilities

Public Facility	LU 2014	LU 2015	LU 2016	LU 2017	LU 2018
University	Built-Up Area 87.5%; Other 12.5%	Built-Up Area 87.5%; Other 12.5%	Built-Up Area 87.5%; Other 12.5%	Built-Up Area 89.6%; Other 10.4%	Built-Up Area 92.0%; Other 8.0%
School	Built-Up Area 90.6%; Other 9.4%	Built-Up Area 90.6%; Other 9.41%	Built-Up Area 91.6%; Other 8.4%	Built-Up Area 92.6%; Other 7.4%	Built-Up Area 93.9%; Other 6.1%
Transportation	Built-Up Area 93.2%; Other 6.8%	Built-Up Area 93.2%; Other 6.82%	Built-Up Area 93.4%; Other 6.6%	Built-Up Area 95.3%; Other 4.7%	Built-Up Area 96.4%; Other 3.6%
Hospital	Built-Up Area 94.7%; Other 5.3%	Built-Up Area 94.7%; Other 5.26%	Built-Up Area 96.1%; Other 3.9%	Built-Up Area 97.4%; Other 2.6%	Built-Up Area 97.4%; Other 2.6%
Religious Place	Built-Up Area 84.9%; Other 15.2%	Built-Up Area 84.9%; Other 15.15%	Built-Up Area 86.4%; Other 13.6%	Built-Up Area 86.4%; Other 13.6%	Built-Up Area 88.9%; Other 11.1%
Park	Built-Up Area 78.0%; Other 22.0%	Built-Up Area 78.0%; Other 22.0%	Built-Up Area 86.4%; Other 13.6%	Built-Up Area 89.8%; Other 10.2%	Built-Up Area 89.8%; Other 10.2%
Police Station	Built-Up Area 95.4%; Other 4.6%	Built-Up Area 95.4%; Other 4.63%	Built-Up Area 93.5%; Other 6.5%	Built-Up Area 95.4%; Other 4.6%	Built-Up Area 96.3%; Other 3.7%
Sport Facility	Built-Up Area 90.0%; Other 10.0%	Built-Up Area 90.0%; Other 10.0%	Built-Up Area 90.0%; Other 10.0%	Built-Up Area 95.0%; Other 5.0%	Built-Up Area 95.0%; Other 5.0%

land change into a built-up area category. These findings provide insight into the questions underlying this research. These findings provide insight into the questions underlying this research and encourage further research on how to determine the appropriate location for developing various supporting facilities by understanding the environmental transformation of the existing urban campus. The relationship between campus locations and neighborhood characteristics, such as demographics and income, also requires further research.

The limitations of data and methods in this study indicate an opportunity to conduct further studies. Further research can be conducted to analyze the relationship between campus locations and neighborhood characteristics (such as demographics and income). Barrow found that the neighborhood characteristics influenced the location of private schools [14]. However, it is necessary to demonstrate further whether these findings are also relevant for higher education levels.

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REFERENCES

[1] S. Carlson, "For Making the Most of College, It's Still Location, Location, Location.," Chron. High. Educ., vol. 59, no. 22, pp. 1–4, 2013.

[2] F. A. Nuzir and B. J. Dewancker, "Understanding the Role of Education Facilities in Sustainable Urban Development: A Case Study of KSRP, Kitakyushu, Japan," Procedia Environ. Sci., vol. 20, pp. 632–641, 2014.

[3] D. L. Widaningrum and K. Mahardini, "Spatial characteristic of urban campus in Indonesia," in IOP Conference Series: Earth and Environmental Science, 2018, vol. 195, no. 1.

[4] D. L. Widaningrum and A. Andika, "Analysis of campus locations concerning the nearby point-of-interests and public facilities," in IOP Conference Series: Earth and Environmental Science, 2020, vol. 426, no. 1.

[5] D. L. Widaningrum, I. Surjandari, and D. Sudiana, "Discovering spatial patterns of fast-food restaurants in Jakarta, Indonesia," J. Ind. Prod. Eng., pp. 1–19, Sep. 2020.

[6] W. Tobler, "A Computer Movie Simulating Urban Growth in the Detroit Region," Econ. Geogr., vol. 46, p. 234, 1970.

[7] H. Winarso, D. Hudalah, and T. Firman, "Peri-urban transformation in the Jakarta metropolitan area," Habitat Int., vol. 49, pp. 221–229, 2015.

[8] S. Vaisi, H. Alizadeh, W. Lotfi, and S. Mohammadi, "Developing the ecological footprint assessment for a university campus, the component-based method," Sustain., vol. 13, no. 17, pp. 1–18, 2021.

[9] A. M. S. Mohammed and T. Ukai, "University campuses as agents for urban change," Environ. Socio-Economic Stud., vol. 10, no. 1, pp. 22–37, 2022.

[10] M. Cetin, T. Aksoy, S. N. Cabuk, M. A. Senyel Kurkcuoglu, and A. Cabuk, "Employing remote sensing technique to monitor the influence of newly established universities in creating an urban development process on the respective cities," Land use policy, vol. 109, no. July, p. 105705, 2021.

[11] R. A. A. Indriyani and D. L. Widaningrum, "A spatial equity assessment of the public facilities in the greater Jakarta area using Moran's I spatial autocorrelation," IOP Conf. Ser. Earth Environ. Sci., vol. 794, pp. 1–10, 2021.

[12] B. W. Silverman, Density Estimation for Statistics and Data Analysis. London and New York: Chapman & Hall/CRC, 1986.

[13] D. W. Allen, GIS tutorial 2: Spatial analysis workbook. California: Esri Press, 2016.

[14] L. Barrow, "Private school location and neighborhood characteristics," Econ. Educ. Rev., vol. 25, no. 6, pp. 633–645, 2006.