International Journal of Technology

http://ijtech.eng.ui.ac.id

Research Article

Mapping Critical Success Factors of Open Innovation in the Indonesian Manufacturing Industry Using Fuzzy Delphi

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Abstract: This study aims to map Critical Success Factors (CSFs) in the implementation of open innovation (OI) in the Indonesian manufacturing industry. The initial identification of critical factors was conducted through a review of relevant literature, while the filtering process to determine the most significant CSFs was conducted using the Fuzzy Delphi method (FDM). The literature review resulted in 15 initial CSFs. Furthermore, 11 CSFs were deemed relevant and 4 others were deemed irrelevant through FDM involving 15 expert panels from academia and manufacturing industry practitioners. Of the 11 accepted CSFs, the four most crucial factors in supporting successful OI implementation are: leadership commitment, mutual trust, intellectual property protection strategy, and government support. Meanwhile, the four factors considered less influential in the context of Indonesia's manufacturing industry are: employee competence, corporate strategy, internal social cohesion, and digital capability and readiness. The practical implication of these findings is the availability of clearer guidance for industry players and the government regarding the critical factors that need to be considered and prepared to improve the success of OI implementation in the manufacturing sector.

Keywords: Critical success factors; Indonesia; Manufacturing; Open innovation

1. Introduction

Today's manufacturing industry faces increasing global challenges, ranging from exponential technological intensity growth, a volatile global environment, the drive to increase productivity and efficiency, complex customer needs, shorter product life cycles, fierce competition, resource scarcity, and increasingly expensive innovation activities. These challenges provide a significant impetus to the manufacturing industry's transformation process to make further investments in the development of Open Innovation (OI) strategies (Obradovic et al., 2021). From a strategic perspective, the expansion of the availability of knowledge and technology resources that exist outside the company allows companies to rethink the ways of generating ideas that have been done so far and begin to shift to fully embrace the OI approach (Nguyen et al., 2023; Alassaf et al., 2020). In addition, the development of the fourth Industrial Revolution (Industry 4.0) has enabled manufacturing industry leaders to integrate intelligent manufacturing processes supported by emerging technologies into their product development cycle and accelerate innovation

https://doi.org/10.14716/ijtech.v16i6.8046
Received August 2025; Revised September 2025; Accepted November 2025

(Surjandari et al., 2022). However, previous research states that although OI has been recognized as a key success factor in increasing companies' competitiveness, many challenges are faced in its implementation, especially in industries in developing countries (Chaudhary et al., 2022; Greco et al., 2022). Several studies have examined the critical success factors (CSFs) influencing the implementation of open innovation (OI) across different contexts. Nevertheless, limited research has quantified the degree of consensus on these factors within EMEs.

This study aims to identify and prioritize OI CSFs in Indonesia's manufacturing sector using the FDM. The findings are expected to contribute to the development of a contextualized, expert-validated model that integrates the organizational, relational, and institutional determinants of OI success.

2. Materials and Methods

2.1 Open Innovation (OI)

OI can be defined as a new paradigm, where companies can and should use ideas and smart minds from external and internal companies and/or use internal and external channels to innovate new products and technologies to be delivered to the market. As the literature on this topic has evolved, the definition has been extended to a distributed innovation process based on the intentional flow of managed knowledge across organizational boundaries, using mechanisms that fit the business model of an organization (Sengupta and Sena, 2020). Furthermore, OI refers to a company's deliberate strategy of accessing and leveraging external knowledge, technologies, and resources beyond its organizational boundaries, with the aim of accelerating internal innovation and expanding market reach (Dubouloz et al., 2021). Meanwhile, Yun et al., 2020 stated that OI is a holistic approach to innovation management that leverages both internal and external sources to systematically expand opportunities for innovation. Audretsch and Belitski, 2023 stated that the primary motivation behind OI adoption is to leverage knowledge spillovers and accelerate product development by collaborating with external partners. Accordingly, OI can be seen as a concept that reshapes innovation strategies through new practices to foster complementary knowledge and technologies.

At a fundamental level, OI can take three different forms: inbound OI, outbound OI, and coupled OI (Gassmann and Enkel, 2004). From a contemporary perspective, inbound OI transcends the mere absorption of external knowledge to complement internal capabilities. It emphasizes the systematic exploration, integration, and cocreation of knowledge and technologies with external stakeholders through digital platforms, collaborative networks, and innovation ecosystems. Rather than simply enriching the internal knowledge base, inbound OI is increasingly viewed as a dynamic process of knowledge recombination and value co-creation, enabling firms to respond more rapidly to technological change, reduce uncertainty, and seize emerging opportunities (Chaudhary et al., 2022). Inbound OI refers to the purposeful inflow of external resources and knowledge into the firm to enhance its internal innovation base. Such activities can take multiple forms, including technologies in-sourcing and in-licensing, minority equity investments, acquisitions, joint ventures, and collaborative R&D initiatives. Firms may also engage in research funding, purchase specialized technical and scientific services from external providers, or actively involve their customers as co-creators of innovation. Collectively, these mechanisms allow firms to tap into complementary expertise and accelerate the innovation process (Dubouloz et al., 2021). Meanwhile, OI refers to the inside–out flow of a firm's knowledge and resources, whereby external organizations are allowed to commercialize internal ideas and technologies. This approach helps companies externalize innovation efforts and bring underutilized ideas to market more rapidly (Greco et al., 2022). Lastly, the coupled OI form reflects the simultaneous use of both inbound and outbound processes in collaborative arrangements. In this model, firms work closely with complementary partners—such as suppliers, customers, competitors, universities, or research institutions—through alliances, joint ventures, and other cooperative structures. Companies jointly develop, refine, and commercialize innovative outcomes by combining the inflow of external knowledge with the outflow of internal ideas and technologies. This form of OI accelerates the innovation process and distributes risks, costs, and benefits across multiple actors in the innovation ecosystem (Rouyre and Fernandez, 2019).

2.2 Critical Success Factors for Implementing Open Innovation

The OI implementation process involves many actors, both internal and external to the company. It is a very complicated and elusive process that often faces complex challenges involving various determinants of success (Albats et al., 2021). The following section describes the CSFs for OI implementation, especially in the manufacturing industry.

2.2.1 Employee Competence

Previous research found that employee competence related to employees' level of education and skills has a significant influence on the success of OI implementation. Bilichenko et al., 2022 stated that OI activities function most effectively when employees with higher educational qualifications are involved, as they are better equipped to manage and integrate external knowledge. In addition, Marzi et al., 2023 stressed that employees must possess the necessary skills of screening, interpreting, and assimilating knowledge received from outsiders to effectively absorb and exchange knowledge and technology with external parties. Belitski et al., 2024 emphasized that in the manufacturing and high-tech industries, the proportion of employees who have degrees with high qualifications in science, technology, engineering, and math (STEM) is very supportive in product development cooperation projects with external partners.

2.2.2 Employee Behavior and Attitude

Employee behavior and mindset is a significant challenge for companies in OI implementation. According to Bogers et al., 2018, individual behaviors and attitudes greatly affect the company's process and innovation activities. Even if an employee has high knowledge and skills qualifications, if he/she does not have a positive attitude toward OI, it will be a big obstacle in the implementation of OI (Mody et al., 2020; Hartono, 2018). S. Zhang et al., 2018 studied OI in the manufacturing industry in China and found that the role of individual behavior and attitude is very large in influencing the performance of OI implementation.

2.2.3 Leadership Commitment

The commitment of company leaders is a challenge and crucial for OI implementation (Haim-Faridian, 2023). Subtil de Oliveira et al., 2018 concluded that one of the critical factors in OI implementation is the individual factors of leaders (such as leader commitment and leader capability). Oumlil et al., 2016 concluded that the primary barrier to successful OI implementation often stems from insufficient support at the top management level. Limited leaders' understanding of OI frequently generates misperceptions regarding its risks and costs, which in turn hampers the decision-making process and constrains the firm's ability to effectively adopt OI (Marzi et al., 2023). Ahn et al., 2013 conducted research onClick here to enter text. the manufacturing industry in Korea and found that CEO traits are very decisive in the OI implementation process.

2.2.4 Organizational Culture

Previous research found that organizational culture is a factor that greatly determines a company's success in OI implementation (Sa et al., 2025; Malek and Desai, 2019). A strong corporate culture can reduce employee resistance to OI by influencing their mindset (Bilichenko et al., 2022). Ullah et al., 2024 stated that organizational culture is a strong dependent variable on the success of OI implementation. In addition, Cricelli et al., 2023 mentioned that several aspects related to organizational culture, such as Not Invented Here/Not Sold Here syndromes, misalignment between partners' organizational cultures, and individual-level resistances, are factors that cause many OI implementation failures.

2.2.5 Absorptive Capacity

Salmeron et al., 2025 stated that absorptive capacity determines the success of OI implementation in the manufacturing industry because it is closely related to the company's ability to assess and recognize new information coming from outside the company as well as its ability to assimilate and use it to provide commercial benefits for the company. On the other hand, Belitski et al., 2024 stated that increasing absorption capacity will reduce transaction costs in the OI implementation process. Cavallo et al., 2025 emphasized. that the absorptive capacity factor is a critical factor in the OI implementation process because it is closely related to the company's ability to adopt new knowledge and technology from outside the company.

2.2.6 Mutual Trust

Previous research shows that company collaboration with various external parties is strongly influenced by aspects of mutual trust. Terhorst et al., 2024 said that the element of trust plays a pivotal role in facilitating the exchange of both tacit and explicit knowledge among parties engaged in collaboration, as it reduces uncertainty and promotes openness in knowledge sharing in OI implementation. In their research in the Korean manufacturing industry, Jang et al., 2017 found that the mutual trust factor has a significant effect on sustainable relationships between collaborative partners in the OI implementation process. Subtil de Oliveira et al., 2018 argued that network and relational factors—such as effective relationship management, mutual benefits, and trustworthy partnerships—serve to strengthen inter-organizational ties. These factors significantly facilitate companies in conducting inter-organizational collaboration to support OI implementation and can even lead to substantially reduced transaction costs in some cases.

2.2.7 The Company Strategy

Previous studies have found that innovation and corporate strategies play an important role in maximizing the OI implementation process in the manufacturing industry (Subtil de Oliveira et al., 2018). Cricelli et al., 2023 found that several elements related to corporate strategy, such as misalignment between partners' goals, prevalence of the closed innovation model, lack of dynamic capabilities, and lack of an adequate business model, are factors that cause many unsuccessful OI implementation processes. In an empirical study, Bagherzadeh et al., 2020 showed that corporate strategy and innovation are mediating factors connecting OI and corporate innovation performance.

2.2.8 Intellectual Property Strategy

Some studies have stated that intellectual property rights issues often become an obstacle to the adoption of OI (Lianto et al., 2025; Sa et al., 2025; Lundaeva and Gintciak, 2025). Konstari and Valkokari, 2024 stated that IP strategy is a crucial factor that determines and influences a company's interest in developing sustainable open innovation. Nguyen et al., 2023 stated that IP protection is a much-needed driver in the OI adoption process, especially in developing countries and at the scale of small and medium industries. Sa et al., 2025 stated that IP strategy has a positive influence on the success of OI implementation.

2.2.9 Internal Social Cohesion

Several studies on manufacturing companies in various countries found that internal collaboration capabilities, such as internal collaboration (G. Zhang and Tang, 2017) and integration between functions (Zeng et al., 2017), significantly influence the company's capability to implement OI. Subtil de Oliveira et al., 2018 stated that weak social cohesion and an unfavorable work climate are the primary challenges in fostering cooperation across different sections of a company. However, when social cohesion is strong, it encourages information exchange and a culture of learning and knowledge sharing, which are indispensable in supporting the success of OI implementation. In addition, Majuri, 2022 stated that the inability of employees to build co-creation between sections is often an obstacle to intra-organizational cooperation.

2.2.10 Internal Support for Management

Previous research has found that internal management support is a critical factor in supporting OI implementation. Alam et al., 2022 stated that internal management support, especially related to senior management's decision-making process, greatly helps the OI adoption process. Cavallo et al., 2025 explained that there are 2 important elements in a company's internal management that support the implementation process: the organizational structure and the decision-making system. Cricelli et al., 2023 even stated that rigid organizational structure/excessive bureaucracy is a cause of OI adoption process failure. However, Bagherzadeh et al., 2020 stated that OI implementation requires a set of appropriate internal practices to effectively cooperate with external partners to integrate their knowledge into the internal innovation process.

2.2.11 Governmental Support

In a study in Asia, Ullah et al., 2022 stated that government support and active involvement are key determinants in the adoption of open innovation. In contrast, Kowalski and Mackiewicz, 2021 found similarities in the characteristics of OI clusters in Thailand, Singapore, South Korea, and China, where the top–down approach highlights the influence of government regulations, decisions, and public sector policies in shaping the development of OI clusters. Government initiatives and support, particularly in establishing such clusters, play a central role in facilitating the implementation of OI among participating actors. Factors such as geographical proximity, alignment of innovation policies, access to market information, and availability of funding provide favorable conditions for the successful implementation of OI (Radziwon et al., 2024). In addition, Jang et al., 2017 found that governmental support is indispensable in the OI implementation process in their research on the Korean manufacturing industry.

2.2.12 Digital Technology and Readiness

The role of digital technologies in enhancing manufacturing firms' innovation potential has been widely acknowledged (Babkin et al., 2022; Lokuge et al., 2019). Vanhaverbeke et al., 2024 stated that digital technology and the growth of digital readiness will create significant opportunities for companies to enhance their innovation capabilities in the digital age because digital technology and readiness will provide many opportunities for companies to collaborate with various internal and external parties. Several studies in the manufacturing industry in various countries have shown that digital technology and readiness have a significant influence on OI implementation (Ravichandran, 2018). Urbinati et al., 2018 stated that the company's digital technology capability will support the company in managing the flow of information and knowledge from outside and inside the company in the OI implementation process.

2.2.13 R&D Capability

Previous research in the manufacturing industry shows that R&D capability is a decisive factor for the development of innovation capability, especially in large-scale industries (Dong and Netten, 2017; C. H. Hsu et al., 2017). R&D capability will improve a company's ability to update its technological knowledge and maintain its ability to redesign a product to make it easier to use, increase the range of customized options, make radical changes to product definitions, and open a new market (Kocoglu et al., 2012). On the other hand, Schaper et al., 2023 stated that R&D capability, as measured by R&D intensity, has a significant influence on a company's success in adopting OI.

2.2.14 External Collaboration Capabilities

Several studies in the manufacturing industry in various countries found that external collaboration capabilities, such as the ability to manage partners and have cooperative networks and good external interaction, significantly contribute to the successful adoption of open innovation (Santoro et al., 2018; Wang and Hu, 2017). Several studies have confirmed that social interactions and the networks in which organizations are embedded shape the successful implementation of open innovation (Naruetharadhol et al., 2022; Guan and Liu, 2016).

2.2.15 Innovation ecosystems (IEs)

Previous research concluded that the innovation ecosystem, such as the existence of a supportive environment with diverse actors (incubators, startups, universities, accelerators, and clusters), will greatly support innovation collaboration (Khoirunisa et al., 2023). Xie and Yu, 2025 assert that innovation ecosystems have a positive influence on the occurrence of collaborative innovation because they can facilitate knowledge acquisition and make cooperation between parties more stable and sustainable. Reiter et al., 2024 stated that structuring and managing the innovation ecosystem will make a positive contribution to open innovation governance.

2.3 Method

The research process was conducted in two main stages, as shown in Figure 1.

2.3.1 Identification of the initial CSFs

The process of identifying the initial CSFs was conducted by conducting a literature study. The selected literature sources are the top ten technology and innovation management specialty journals proposed by Thongpapanl, 2012, namely: Research Policy, Journal of Product Innovation Management, Research-Technology Management, Technovation, R&D Management, Industrial and Corporate Change, IEEE Transactions on Engineering Management, Journal of Technology Transfer, Technological Forecasting and Social Change, and Journal of Engineering and Technology Management. To get a picture of the current conditions, the study was directed to the latest journal articles published in the period 2018-2025. Next, the initial CSFs obtained from the literature study were validated using a involving manufacturing industry practitioners. The purpose of this process was to ensure that the initial CSFs obtained from the literature study were appropriate and relevant to the context of the manufacturing industry in Indonesia.

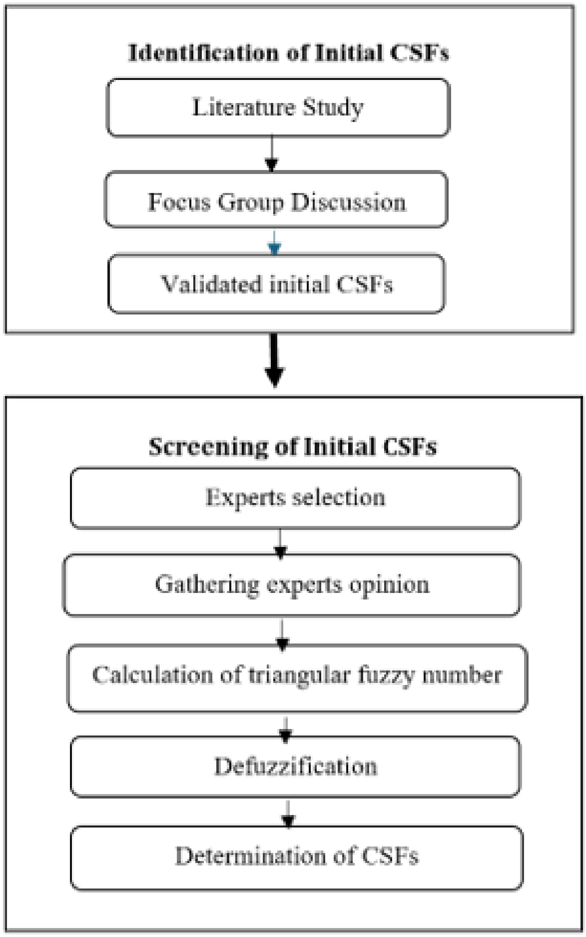

Figure 1 Flowchart of research steps

2.3.2 Screening of the initial CSFs

The initial CSF screening process was conducted using the FDM, which is an analytical method based on the Delphi method and fuzzy theory. FDM, originally developed, combines the traditional Delphi method with fuzzy set theory to achieve expert consensus by overcoming the vagueness and ambiguity in human judgment. This approach improves the accuracy and efficiency of the conventional Delphi process by utilizing fuzzy theory, which helps represent situations where experts cannot express their opinions precisely (Padilla-Rivera et al., 2021). According to Lee and Hsieh, 2016, the application of fuzzy theory minimizes the distortion of individual experts' views, captures the semantic relationships between the items being evaluated, and considers the inherent uncertainty in the collected data. As a result, FDM requires fewer expert participants while providing a more comprehensive representation of expert knowledge. The advantage of FDM over methods such as AHP, DEMATEL, or ISM is its ability to integrate all expert opinions into a unified consensus, thereby reducing the time and costs associated with analysis and decision-making. FDM is a collaborative decision-making method that involves experts and has been widely used in various fields (C. H. Hsu et al., 2017). In this study, the fuzzy Delphi method (Y. L. Hsu et al., 2010) was used to show the agreement of experts using a geometric mean approach. The FDM steps are as follows:

- Expert Selection
  The panel of experts involved in this research includes industry experts and academics. Experts were selected using knowledge and skills (C. H. Hsu et al., 2017). Academics are experts in industrial engineering, manufacturing systems, engineering and technology management, and mechanical engineering. The experts had at least a doctorate with a good research track record. Industrial experts from national manufacturing industries in Indonesia were selected from those who work in production, engineering, product and process development, business development, R&D, and technology development and occupy positions as middle and senior managers for 10 years. A total of 20 experts (10 academic and industry experts each) met the abovementioned criteria. Next, the researcher confirmed their willingness through a phone call with a questionnaire containing the initial CSF sent via email in the form of a Google Survey Form. In practice, only 15 experts (7 academic experts and 8 industry experts) were willing to complete and return a valid questionnaire, resulting in a survey response rate of 75%. This number (15 experts) has met the requirement where the size of homogeneous experts ranges from 10 to 15 people (Manakandan et al., 2017). The following are the profiles of industry and academic experts in this study.The demographic characteristics of respondents are attached in the Appendix section.

- Gathering Experts' Opinions
  The experts' opinions were collected through a structured questionnaire consisting of two sections. The first section gathers general information and expert profiles, while the second section evaluates the importance of the initial CSFs. The weightings were assessed using linguistic terms on a 7-point Likert scale and analyzed using fuzzy scales (Table 2).

Table 1 List of industry and academic experts

Industrial Experts	Position	Sector	Academician Expert	Field of expertise
E1	President Director	Food	E9	Industrial engineering
E2	President Director	Pharmacy	E10	Manufacturing engineering
E3	Operational Director	Steel	E11	Mechanical engineering
E4	Production Director	Paper	E12	Industrial engineering
E5	Plant Manager	Building Material	E13	Industrial and System Engineering
E6	President Director	Leather and footwear	E14	Industrial engineering
E7	President Director	Cosmetic	E15	Technology management
E8	Director	Furniture		

Table 2 Linguistic variables for weight criteria's importance

Linguistic variable	Fuzzy scale
Absolutely Unimportant	(0.0,0.0,0.1)
Unimportant	(0.0,0.1,0.3)
Slightly Unimportant	(0.1,0.3,0.5)
Neutral	(0.3,0.5,0.7)
Slighty Important	(0.5,0.7,0.9)
Important	(0.7,0.9,1.0)
Absolutely Important	(0.9,1.0,1.0)

- Calculation of Triangular Fuzzy Numbers and Defuzzification
  The next step is triangular fuzzy number calculation and defuzzification. This process begins by converting all linguistic terms (1-7 points) into fuzzy scales. For example, the linguistic term 7 is converted into three fuzzy scales, namely 0.9; 1.0; 1.0, with the triangular number calculated using the following formula:

$$a_j = \min\{a_{ij}\} \tag{1}$$

$$b_j = \frac{1}{n}\sum_{i=1}^{n} b_{ij} \tag{2}$$

$$c_j = \max\{c_j\} \tag{3}$$

Where n = number of experts and m = number of factors/elements. The researchers then calculated defuzzification using the following formula:

$$S_j = \frac{a_j + b_j + c_j}{3}, \quad j = 1, 2, \ldots, m \tag{4}$$

Acceptance or rejection of a factor is carried out according to the following principles:
If $S_i \geq \alpha$, j is accepted.
If $S_i < \alpha$, j is rejected; where $\alpha = 0.75$

3. Results and Discussion

Based on the FGD results, all initial CSFs are relevantconsidered relevant and applicable to the manufacturing industry in Indonesia. Several industry practitioners provided input on factors that are considered important. However, after further discussion, these factors can essentially be included in the existing 15 CSFs by adding to and changing the descriptions of the SCFs. After going through the four stages of the Fuzzy Delphi Method screening with a threshold value of $\alpha \geq 0.75$ (accepted) and $\alpha < 0.75$ (rejected), the results obtained are as shown in Table 4. The appendix contains a summary of expert opinions (Likert scores from experts) and the results of triangular fuzzy number calculations and defuzzification.

From the results above, 11 of 15 CSFs, 11 CSFs are accepted and 4 are rejected. Of the 11 accepted CSFs, 4 have the highest de-fuzzy score (0.89): leadership commitment, mutual trust, intellectual property strategy, and governmental support. The second-highest de-fuzzy score (0.82) was achieved by employee behaviors, mindset, and R&D capabilities. Furthermore, the de-fuzzy score (0.81) was obtained by the absorptive capacity factor and internal management support, and (0.80) was the organizational culture factor, external collaboration capabilities, and innovation ecosystems (0.80). While the 4 CSFs that are rejected because they have a de-fuzzy score 0.75 are employee competency factors, company strategy, internal social cohesion, and digital capability and readiness.

The results of this study indicate that the company's top leadership commitment is a very relevant and crucial factor for the OI adoption process in the manufacturing industry. The results of this study are consistent with those of several previous studies (Wiroonrath et al., 2024; Haim-Faridian, 2023). The strategic role of company leaders in the manufacturing industry is decisive in the decision-making process toward OI implementation. Leaders who do not have sufficient capabilities and an adequate understanding of OI strategies are likely to have wrong views and perceptions of investment costs and risks arising from OI implementation (Marzi et al., 2023). According to Bogers et al., 2018, the right leadership style greatly affects the effectiveness of the OI implementation process. In discussions with several manufacturing industry leaders, forward-thinking, visionary, open, and collaborative leaders tend to have a positive view of OI strategies and continue to strive to build organizational culture and internal capabilities to absorb various knowledge and technology from outside the company. On the other hand, Roberts and Spedale, 2025 stated that transformative leadership styles that are oriented toward change and leadership visions that can inspire and empower followers are more effective in the OI implementation process than transactional leadership styles that are more likely to be short-term oriented. Studies on the role of leadership in the OI adoption process in several Asian countries also show relatively similar results. The following are several factors related to leadership in the OI adoption process in the manufacturing industry in Asia, such as transformational and transactional leadership in Vietnam (Nguyen et al., 2023), leadership commitment in Pakistan (Mehta et al., 2021), positive leadership in Korean (Ko and Choi, 2021), and leadership assessment and transformational leadership in Malaysian (Hosen et al., 2025) industries.

The CSF identification process from the literature study resulted in 15 CSFs as follows (Table 3):

Table 3 Initial CSF count

No	CSFs	Description	Source
1	Employee competencies	Employees' level of education and technical skills are sufficient to cooperate with external parties	(Belitski et al., 2024; Abhari and McGuckin, 2023; Marzi et al., 2023; Bilichenko et al., 2022; Bogers et al., 2018)
2	Employee behavior and mindset	Employees' positive behavior and mindset to interact with external parties and readiness to accept knowledge and technology from outside the company	(Mody et al., 2020; Laursen and Salter, 2020; Bogers et al., 2018; S. Zhang et al., 2018)
3	Leadership commitment	Level of understanding and support of leaders toward OI (actively promoting, allocating resources, and participating in OI initiatives) and perceptions of the level of risk and cost of OI implementation	(Abhari and McGuckin, 2023; Haim-Faridian, 2023; Gad-David et al., 2021; Subtil de Oliveira et al., 2018)
4	Organizational culture	Organizational values and employee mindsets that support knowledge sharing, openness, and mutual trust with external partners	(Shahzad et al., 2024; Abhari and McGuckin, 2023)
5	Absorptive capacity	The company's ability to assess and recognize new information coming from outside the company, assimilate and use it effectively to provide commercial benefits to the company.	(Salmeron et al., 2025; Cavallo et al., 2025; Belitski et al., 2024; Lopes-Bento and Simeth, 2024)
6	Mutual trust	Relationship quality with external partners, characterized by mutual trust, reciprocity, and long-term orientation.	(Terhorst et al., 2024; Subtil de Oliveira et al., 2018; Jang et al., 2017)
7	Company strategy	Long-term plans that align business objectives with innovation efforts, allocate resources to internal and external innovation activities, and encourage collaborative mechanisms to create and capture value from internal and external knowledge sources are in place.	(Abhari and McGuckin, 2023; Cricelli et al., 2023; Bagherzadeh et al., 2020; Subtil de Oliveira et al., 2018)
8	Intellectual property strategy	The company has an IP management system, demonstrated by a clear framework for the sharing and protection of IP.	(Konstari and Valkokari, 2024; Nguyen et al., 2023)
9	Internal social cohesion	Internal collaboration capabilities and integration between company sections enable information sharing.	(Abhari and McGuckin, 2023; Majuri, 2022)
10	Internal management support	Organizational structure and systems, management systems, and decision-making processes for effective collaboration with external partners.	(Cavallo et al., 2025; Shahzad et al., 2024; Cricelli et al., 2023; Abhari and McGuckin, 2023; Alam et al., 2022; Bagherzadeh et al., 2020
11	Governmental Support	A transparent legal framework for collaboration, public funding, policy incentives, and support programs that facilitate open innovation	(Vendrell-Herrero et al., 2025; Radziwon et al., 2024; Ullah et al., 2022; Kowalski and Mackiewicz, 2021; Jang et al., 2017
12	Digital technology and readiness	Availability and use of ICTs to support knowledge sharing and remote collaboration	(Belitski et al., 2024; Vanhaverbeke et al., 2024; Barlatier et al., 2023; Lokuge et al., 2019; Ravichandran, 2018; Urbinati et al., 2018)
13	R&D capabilities	The company's technical competence, infrastructure, and human resources devoted to R&D that facilitate innovation and external collaboration	(Xie and Yu, 2025; Belitski et al., 2024; Lopes-Bento and Simeth, 2024; Abhari and McGuckin, 2023; Schaper et al., 2023)
14	External Collaboration Capabilities	Ability to manage partners to leverage assets and use knowledge with partners and have good external cooperation and interaction networks	(Salmeron et al., 2025; Abhari and McGuckin, 2023)
15	Innovation ecosystem	An enabling environment with diverse actors, such as incubators, startups, universities, accelerators, and clusters that foster innovation and collaboration	(Xie and Yu, 2025, Reiter et al., 2024)

This research also shows that mutual trust is another CSF that is highly relevant in the successful implementation of OI. This is in line with the results of other studies that concluded that the existence of mutual trust among collaborating partners is increasingly recognized as a key factor in the successful implementation of OI (Antonelli et al., 2025). Salampasis et al., 2015 stated that trust is a core element of open innovation. The existence of trust, which is described by a good corporate reputation, a corporate culture that supports openness and high commitment, transparency and clarity, relationship intensity and quality, good personal identity, and a high professional attitude of company employees, will greatly support the quality and sustainability of the process of interaction between parties (Antonelli et al., 2025).

Table 4 CSFs after the FDM screening

CSFs	Score				Results
	Min		Average	De-fuzzy	
Employee competencies	0.3	1.0	0.91	0.74	Rejected
Employee Behavior and Mindset	0.5	1.0	0.95	0.82	Accepted
Leadership commitment	0.7	1.0	0.98	0.89	Accepted
Organizational culture	0.5	1.0	0.91	0.80	Accepted
Absorptive capacity	0.5	1.0	0.94	0.81	Accepted
Mutual trust	0.7	1.0	0.98	0.89	Accepted
Company strategy	0.3	1.0	0.90	0.74	Rejected
Intellectual property strategy	0.7	1.0	0.98	0.89	Accepted
Internal social cohesion	0.3	1.0	0.91	0.74	Rejected
Internal management support	0.5	1.0	0.94	0.81	Accepted
Governmental Support	0.7	1.0	0.98	0.89	Accepted
Digital technology and readiness	0.3	1.0	0.91	0.74	Rejected
R&D capabilities	0.5	1.0	0.95	0.82	Accepted
External Collaboration Capabilities	0.5	1.0	0.91	0.80	Accepted
Innovation ecosystem	0.5	1.0	0.91	0.80	Accepted

Several studies have also shown that mutual trust strongly supports the OI implementation process. It can reduce transactional costs (Subtil de Oliveira et al., 2018) and transactional barriers because it can prevent the emergence of opportunistic behaviors, reduce cultural and communication barriers between parties, and reduce the risk of investment (Antonelli et al., 2025). In some cases, collaborative relationships (industry with universities, suppliers, and other companies) are well established and sustainable in the manufacturing industry in Indonesia due to mutual trust arising from personal closeness (good school friends, siblings, and friendships tested in associations or other institutions). In their study on efforts to increase radical innovation through collaboration between buyers and suppliers in emerging economies in Southeast Asia,Mai Anh et al., 2018 showed that mutual trust is very important in innovation collaboration, especially in supporting the confidence of the parties to share information, risks and benefits, and make joint decisions in the development of new products and services. Furthermore, based on discussions with manufacturing industry practitioners, Asian cultures, including Indonesia, generally emphasize long-term relationships. Therefore, mutual trust is an asset that is nurtured and maintained continuously, rather than merely a temporary transaction.

Another result of this study shows that IP strategy is another CSF that is very relevant to the OI implementation process in the Indonesian manufacturing industry. So far, IP rights have been viewed as only a legal protection aspect. However, the results show that an IP strategy has become a strategic tool in the open innovation ecosystem for organizing collaboration, managing risks, and creating added value. Without a well-thought-out IP strategy, manufacturing companies risk losing control over innovation outcomes and experiencing conflicts in external collaborations. Grimaldi et al., 2021 stated that the existence of a good strategy and management of intellectual property (IP) will be a critical factor in the successful management of open innovation because a company will be actively involved as a buyer and seller of IP. The results of Lianto et al., 2025 research on the collaboration process between universities and the manufacturing industry in Indonesia also show that uncertainty regarding IP rights can be an obstacle in the collaboration process. Toma et al., 2018 stated that IP protection determines the success of R&D collaboration. In their study on OI policy in Southeast Asia from a legal perspective, Smith and Perry, 2023 show the importance of readiness and IPRP policies in maintaining the sustainability of the OI adoption process in Asia.

This research also shows that the role of government support is critical and is one of the determining factors for the success of OI implementation in Indonesia's manufacturing industry. The success of Open Innovation implementation in the manufacturing industry depends not only on companies and collaborative partners but also on the extent to which the government can create a conducive innovation climate. With an active role as a facilitator, resource provider, and policy director, the government is a key element in realizing an inclusive and sustainable OI ecosystem. The role of the government can be in the form of providing clear policies and regulations and encouraging collaboration between innovation actors, such as the super deduction tax policy provided by the Indonesian government for companies that collaborate with universities to carry out R&D activities. Vendrell-Herrero et al., 2025 stated that implementing R&D tax incentives can encourage a collaborative process between industry and research institutions, such as universities. Other roles that the Indonesian government has played include providing subsidies, research grants, financing schemes (such as matching fund programs), building innovation infrastructure (such as establishing 100 science techno parks), human resource capacity building programs (industrial manufacturing digitalization 4.0 training), and assisting market access and global partnerships (ASEAN collaboration platform). Several researchers have highlighted the role of government support as a key factor in the implementation of OI in Asia. In their study on the determinants of OI adoption in Singapore-based family-owned enterprises, Koh et al., 2019 showed that government-supported initiatives are one of the key factors in supporting the successful adoption of OI. Intarakumnerd et al., 2002, in their study on the NIS in Thailand as a developing country, showed that the government has the main role in shaping Thailand's NIS.

The results of this study also found that there are 4 factors that are considered irrelevant and do not affect the success of the OI implementation process in the manufacturing industry in Indonesia: employee competence, company strategy, internal social cohesion, and digital capability and readiness.

Employee competence, which is often measured by a high level of education, does not necessarily reflect the ability to think creatively, manage collaboration risks, understand market dynamics or new technologies, or build open networks. In the context of OI, the ability to adapt, communicate across organizations, and collaborate across sectors is much more important than just an academic background. The results show that employee behaviors and positive attitudes toward OI are far more important than employee competence. Mody et al., 2020 stated that even though an employee has high knowledge and skills qualifications, if he/she does not have positive behaviors and attitudes toward OI, it will be a big obstacle in implementing OI. In their research related to the development of a competency model for OI, Podmetina et al., 2018 stated that OI competencies are very broad. Employee skills and knowledge are only measured by certification and educational degrees. Mortara and Minshall, 2011 once proposed 4 skills that are relevant in OI management: introspective, extrospective, interactive, and technical skills. Chatenier et al., 2010 added four other categories of skills: self-management, interpersonal management, project management, and content management. In their research on continuous innovation capabilities in the Indonesian manufacturing industry, Lianto et al., 2022 also found consistent results, namely that skills and education factors do not significantly influence a company's capabilities in carrying out sustainable innovation.

Meanwhile, the company strategy factor is not considered a critical success factor in OI implementation because the existence of a company strategy does not automatically guarantee the success of OI implementation in the manufacturing industry. Experts, particularly academics, argue that many companies have innovative strategies but lack the systems, culture, and execution to support them. Companies may state their support for open innovation in their strategy documents, but the implementation on the ground is inconsistent. Strategies only become formal documents without real policies, budget allocations, or adequate support systems. In addition, Chesbrough and Appleyard, 2007 stated that traditional business strategies are often limited and cannot adapt to modern business challenges that require open strategies. Hosen et al., 2025 studied the adoption process of OI in the manufacturing industry in Malaysia and found that strategic planning demonstrated an unfavorable impact on OI initiatives, but strategic flexibility, not just having a strategy, supported the OI adoption process. Kratzer et al., 2017 also supported this finding onClick here to enter text. innovation culture and openness in the manufacturing industry in Russia, finding that knowledge and information sharing is generally done voluntarily rather than by request and fulfillment of the company's key performance indicators.

This study also found that the social cohesion factor among company employees is not a critical factor in determining the success of the OI implementation process. Discussions with industry practitioners show that good internal social cohesion can indicate a harmonious working atmosphere, such as a sense of togetherness, solidarity, and trust among a company's members. However, this is not always a measure of a company's ability to generate new ideas and often has the opposite effect due to a tendency to create uniformity that can hinder innovation. Although Lopes-Bento and Simeth, 2024 state that good internal social cohesion will support information sharing and a culture of learning and sharing within the company, the results of this study show that the capability of collaboration with external parties (not internal) and absorptive capacity are more determinants of the success of OI implementation. Chang et al., 2023 conducted similar research in several manufacturing companies in Taiwan and concluded. that normative conformity can reduce employees' innovative performance by weakening their social bonds. However, Shi et al., 2021 conducted research on managing OI from a knowledge perspective in China and showed different results. Relational embeddedness–tie strength, which indicates the degree of cohesive social interaction between network members as a community of internal and external organizations, has a positive influence on inbound OI practices. Another interesting finding from the results of this study is that the digital capability and readiness factor does not determine the success of OI implementation.

The results of discussions with academic experts and practitioners concluded that OI is about openness in the exchange of ideas, knowledge, and resources between organizations. Digital capabilities can indeed facilitate this process, but the essence of OI success lies in the commitment to collaboration, strategy, and organizational culture, not in the technology. Many companies with advanced digital infrastructure fail to implement OI due to a lack of willingness to share, build an open ecosystem, and the degree of openness that is not aligned with the company's development (Liu et al., 2025). Mubarak and Petraite, 2020, in their research on the electrical and electronics industry in three major Asia-Pacific countries, namely Malaysia, Indonesia, and Thailand, found that companies can streamline internal and external collaboration processes by utilizing digital technology, where they can intelligently store, share, and disseminate their valuable knowledge. This can encourage the formation of a more efficient open innovation network, but without digital trust, this will be difficult to achieve. Therefore, several factors, such as trust, culture, risk, and regulation, greatly influence the adoption of digital technology and readiness. Generally, these aspects are not yet ready and mature in developing countries. Previous studies, particularly in developed countries, have shown that digital capability and readiness are the drivers of successful open innovation (Holgersson et al., 2024; Robertson and Lapina, 2023; Kuzior et al., 2023).

4. Conclusions

Although open innovation promises significant benefits for the manufacturing sector, its implementation in developing countries faces highly complex challenges. The main contribution of this research is a validated CSF model for OI in developing manufacturing economies. A literature review identified 15 initial CSFs. After a screening process using the FDM method, which involved 15 panels of academic experts and manufacturing industry practitioners, 11 and 4 CSFs were rejected, respectively. Among the 11 accepted CSFs, there were 4 most relevant: leadership commitment, mutual trust, intellectual property strategy, and government support. Meanwhile, the 4 CSFs that were considered irrelevant and did not influence the success of OI implementation in the Indonesian manufacturing industry were employee competence, corporate strategy, internal social cohesion, and digital capability and readiness. The practical implications of this research provide guidance for policymakers and industry managers. For OI implementation to be successful in the manufacturing sector, these factors must be prioritized and carefully prepared. Company leaders must be fully committed and have a deep understanding of OI strategies, build mutual trust with external partners, develop effective IP strategies, and study various government policies that can support and facilitate OI implementation.

The limitations of this study include the relatively small number of experts and the lack of quantitative validation. Future research should be expanded to multi-country or hybrid fuzzy systems, and the possibility of integrating them with decision support tools (AHP, DEMATEL, or Bayesian methods) for practical implementation should be evaluated. In addition, future research should be careful in recruiting experts, especially older ones because digitization is inevitable in future industrial innovation. Experts may not be aware of future technological and digitization conditions. Digitization is mandatory for future global innovation.

Author Contributions

Benny Lianto: Conceptualization, Methodology, and Original Draft Preparation. Hazrul Iswadi: Survey and Data curation; Bobby Ardiansyahmiraja: Software and Edit-

ing; Ching-Te Lin: Contributed to the enrichment of concepts and discussions.

Conflict of Interest

The authors declare no conflicts of interest.

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International Journal of Technology

Volume 8 | Issue 1 | January 2017

www.ijtech.eng.ui.ac.id

Published by Faculty of Engineering, Universitas Indonesia

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IJTech

p-ISSN : 2086-9614 (https://portal.issn.org/resource/ISSN/2086-9614)
e-ISSN : 2087-2100 (https://portal.issn.org/resource/ISSN/2087-2100)

Journal Metrics

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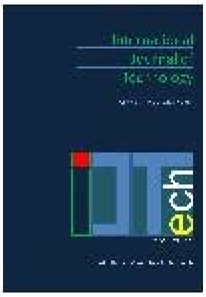
Volume 16, Number 6



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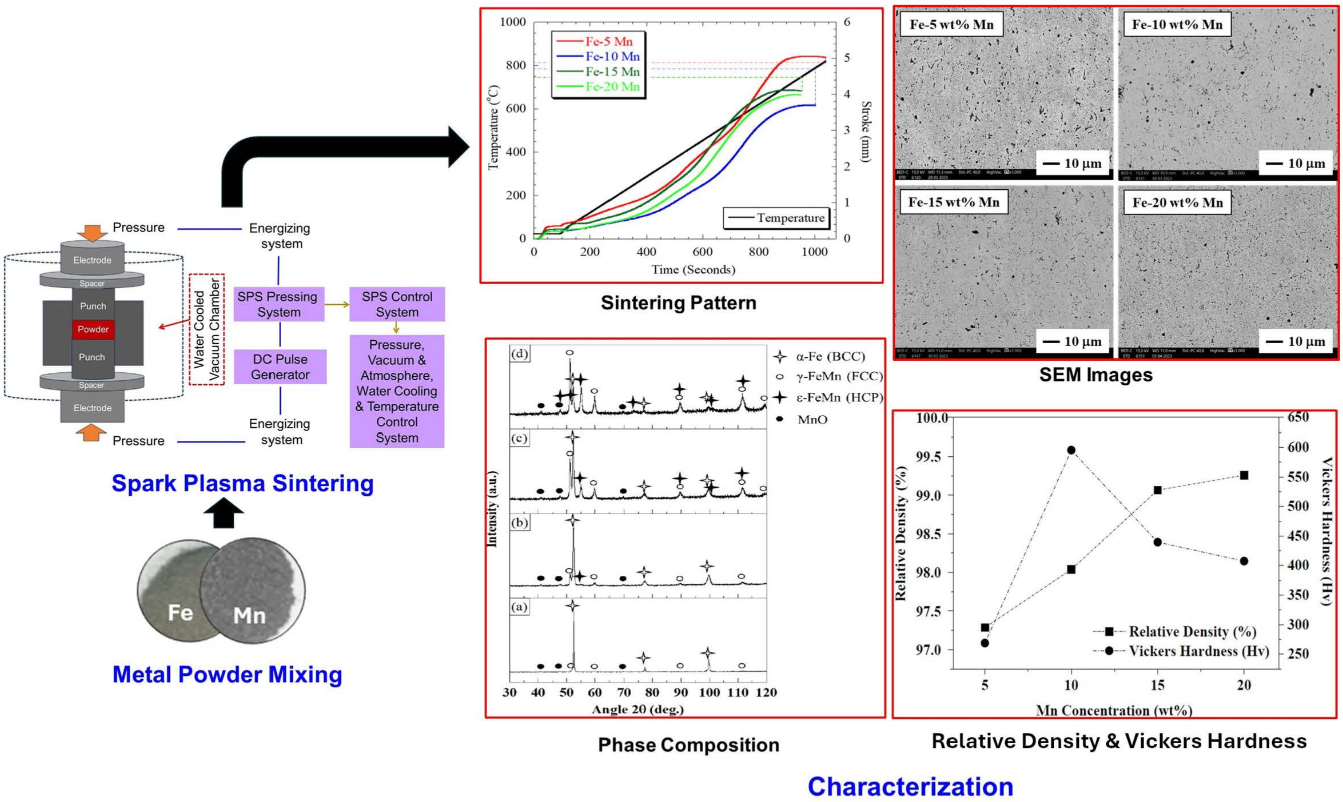

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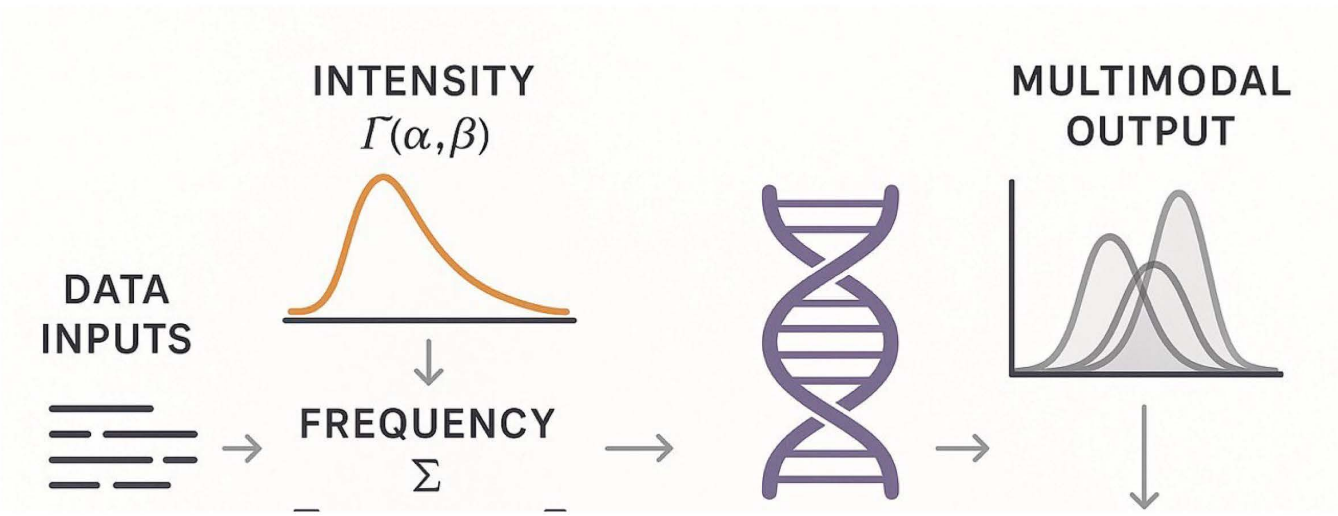

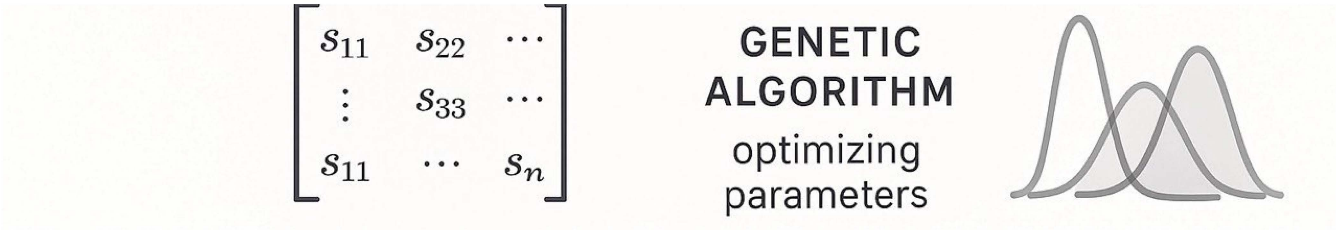

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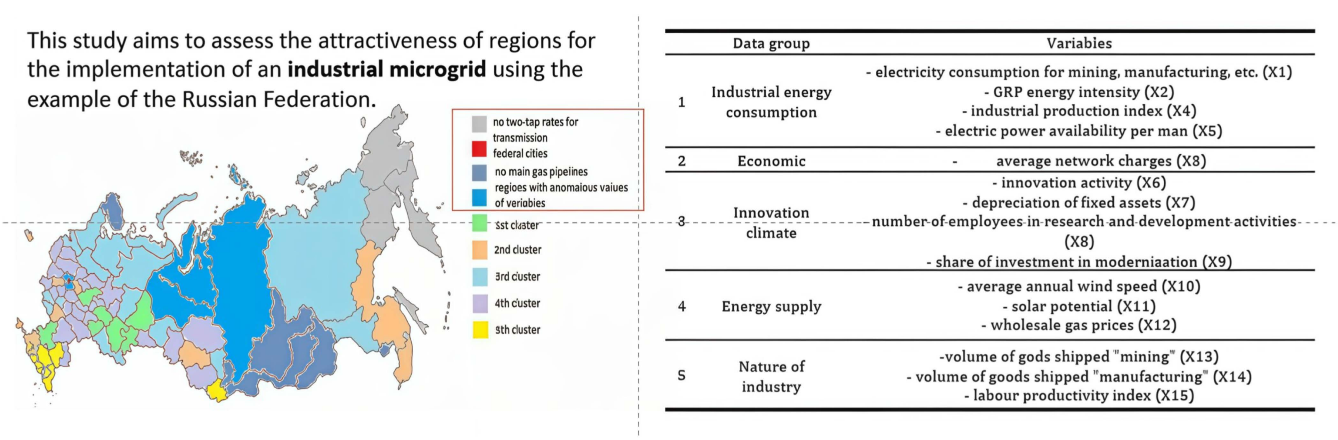

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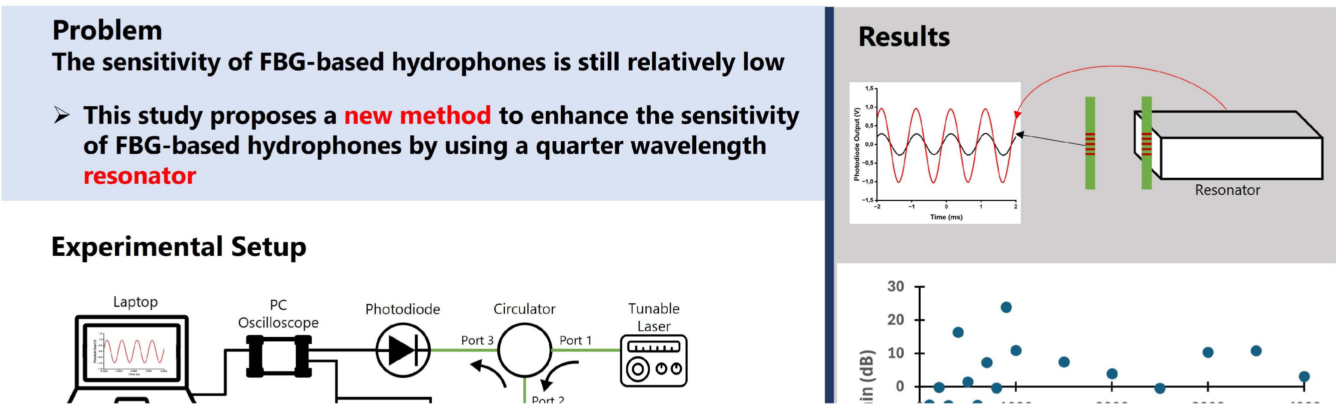

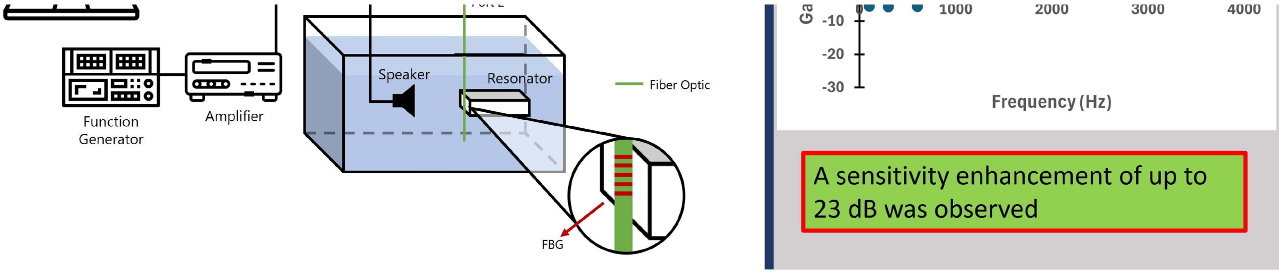

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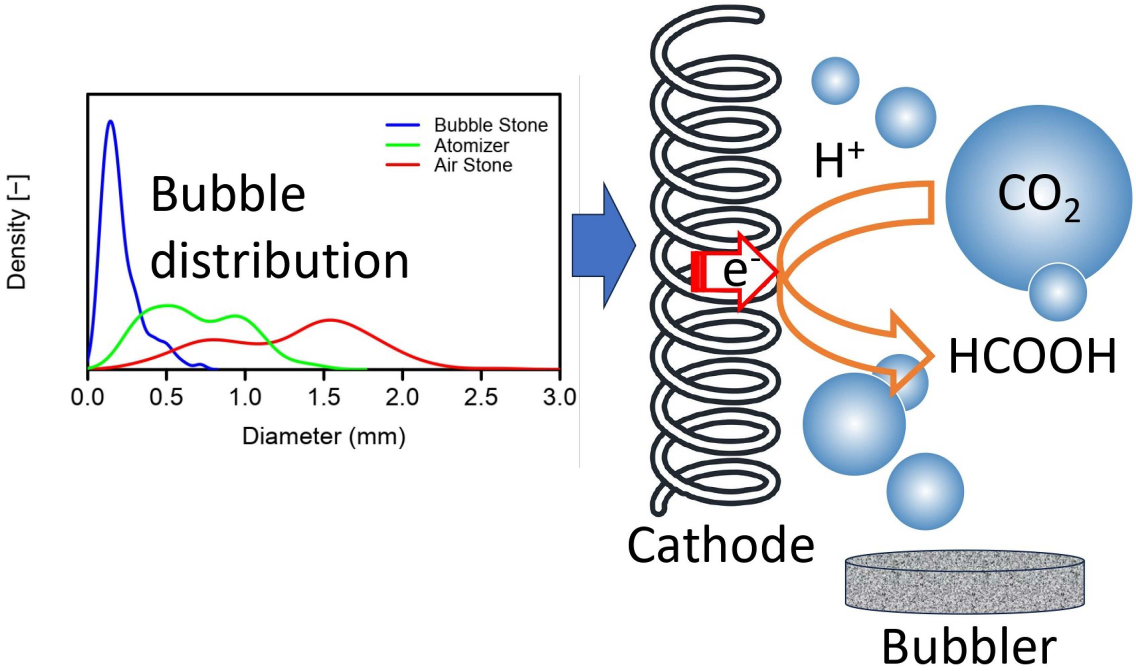

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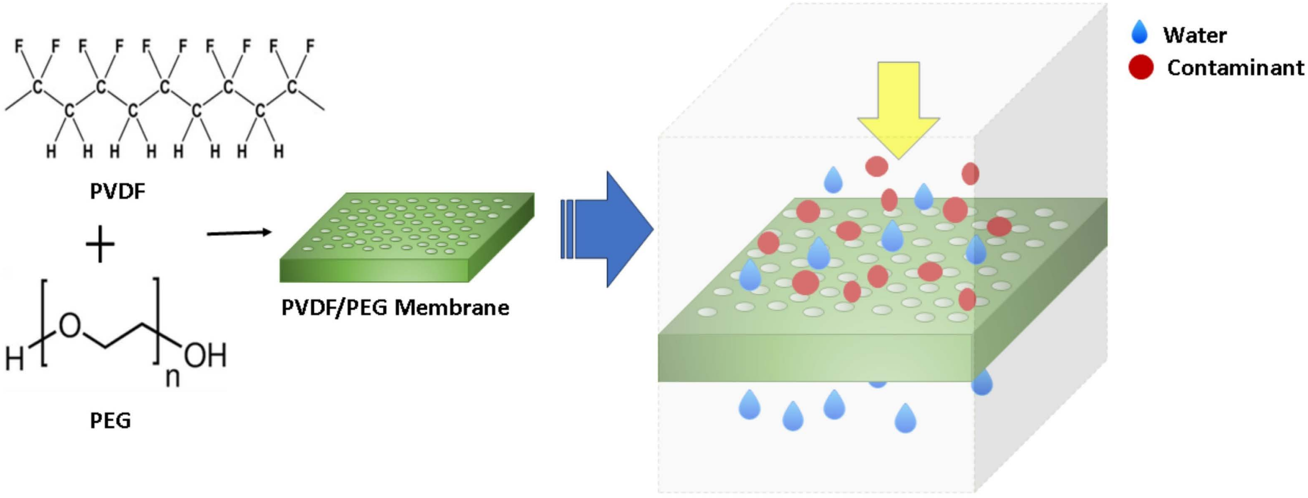

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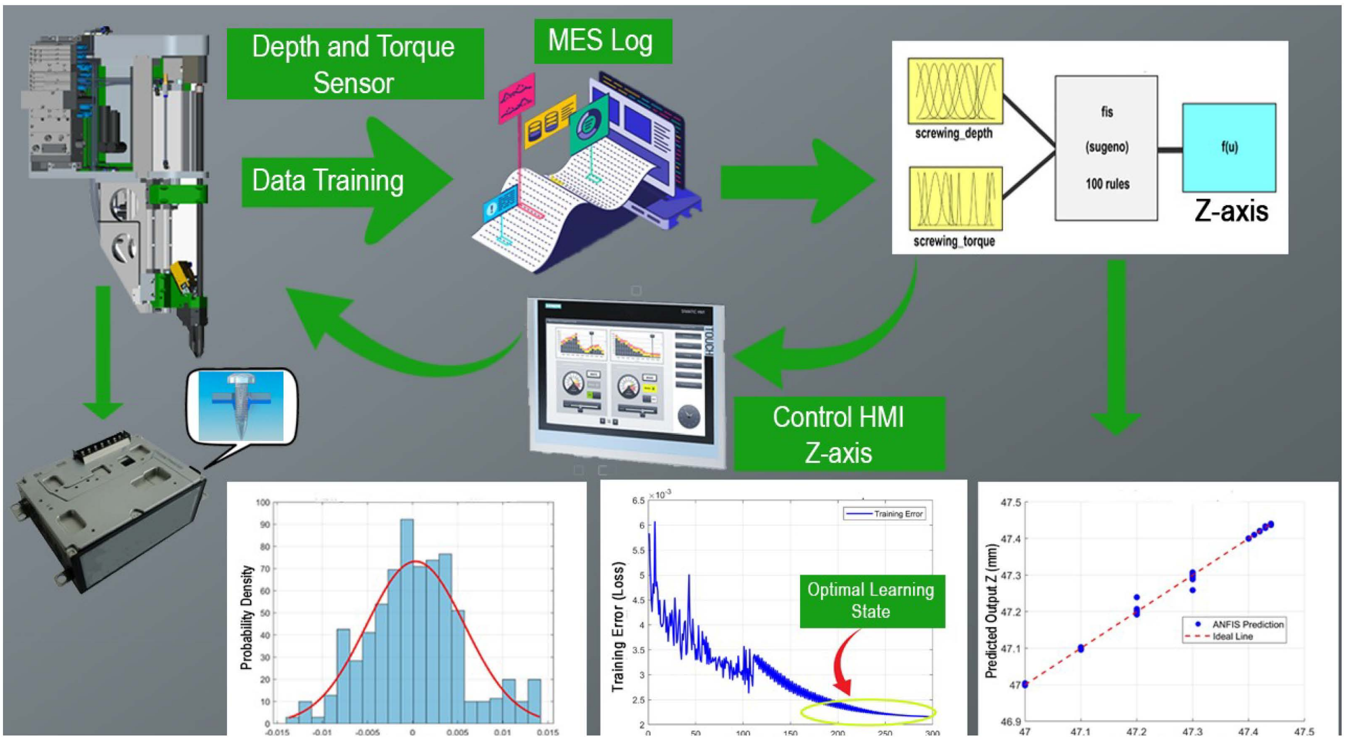

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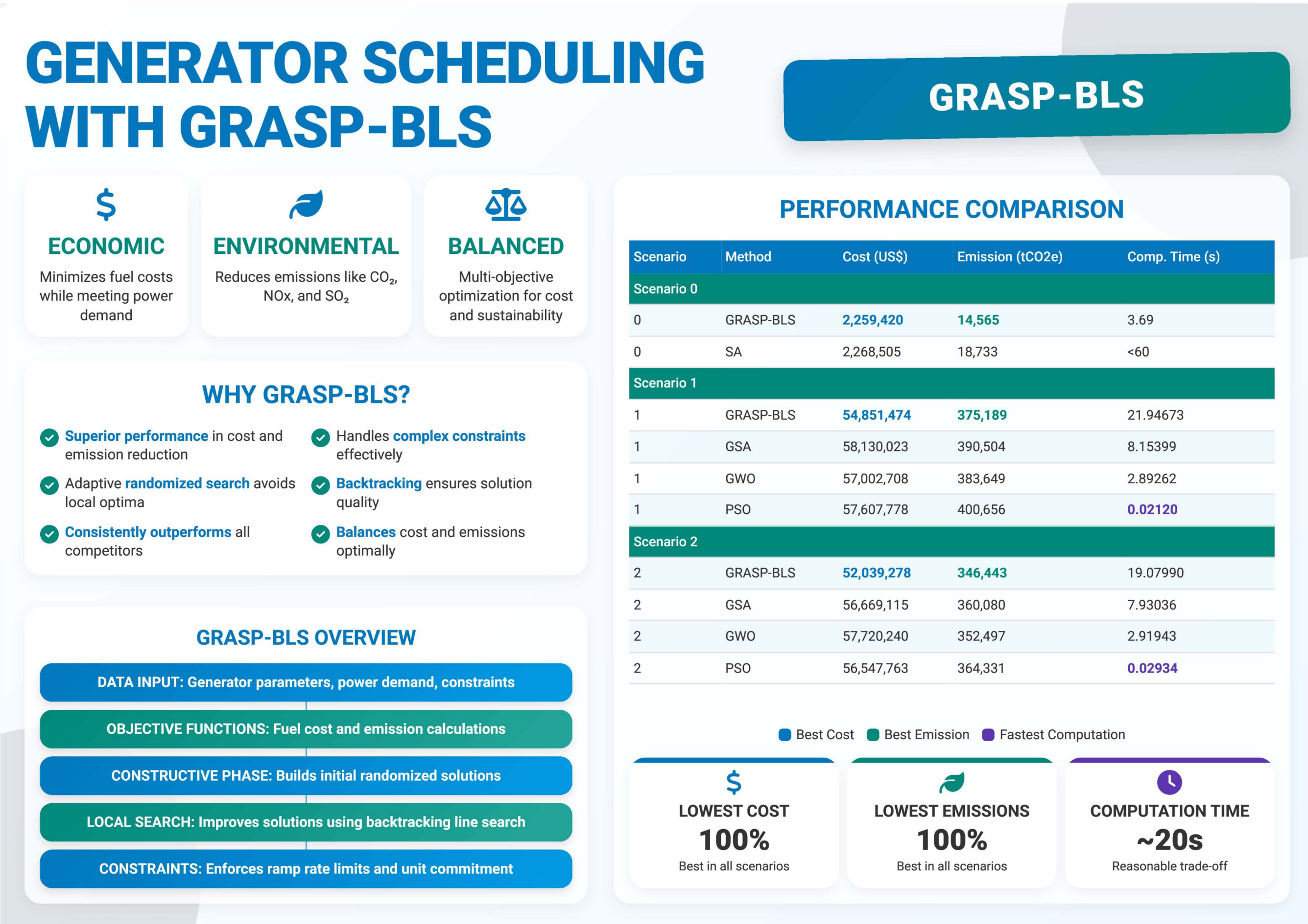

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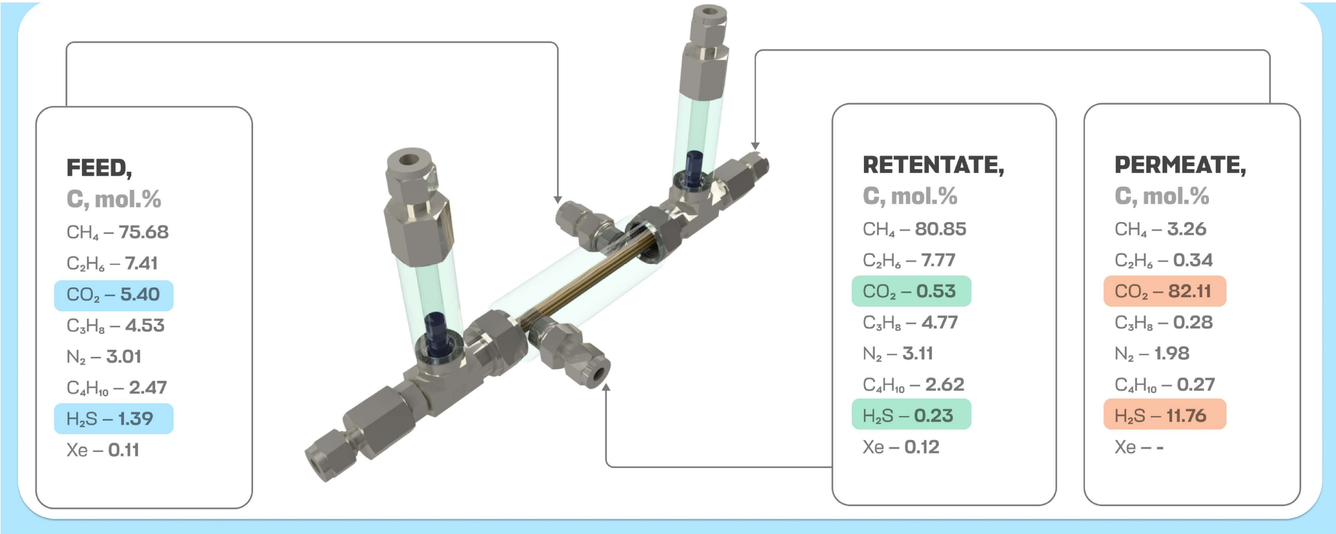

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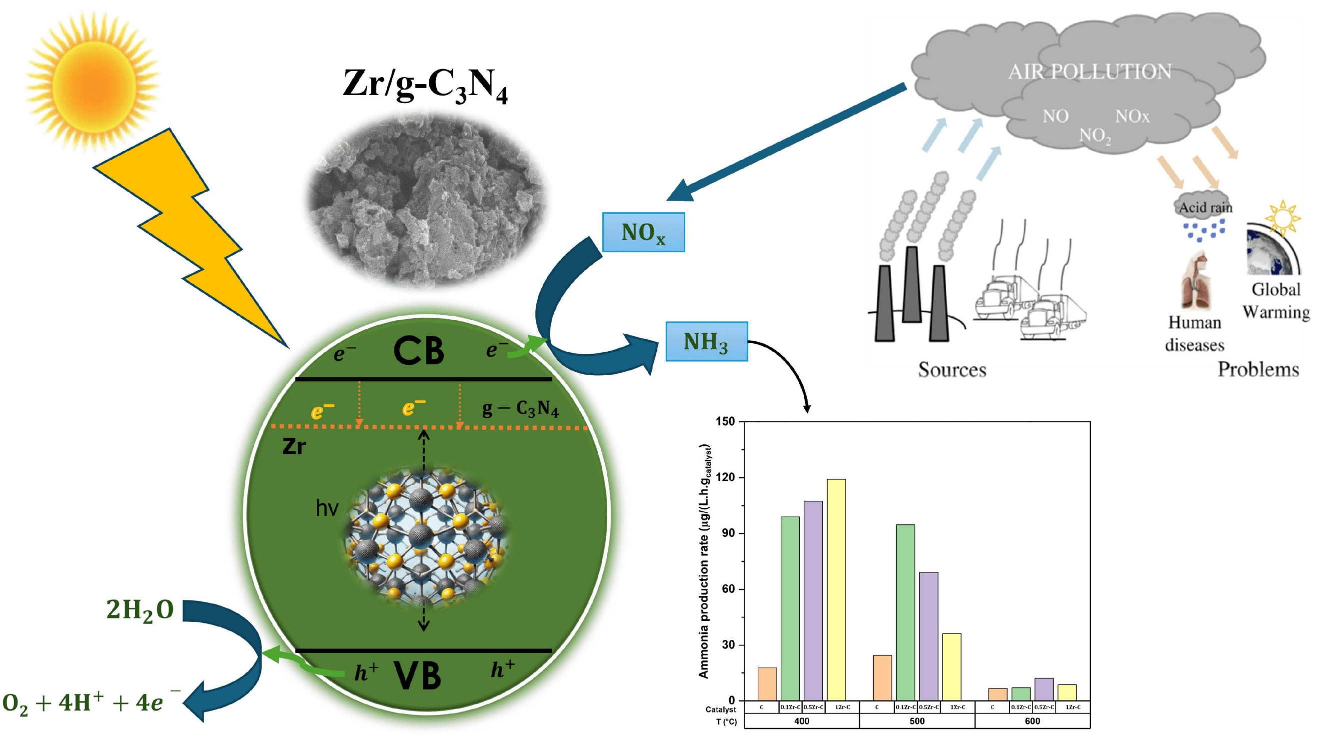

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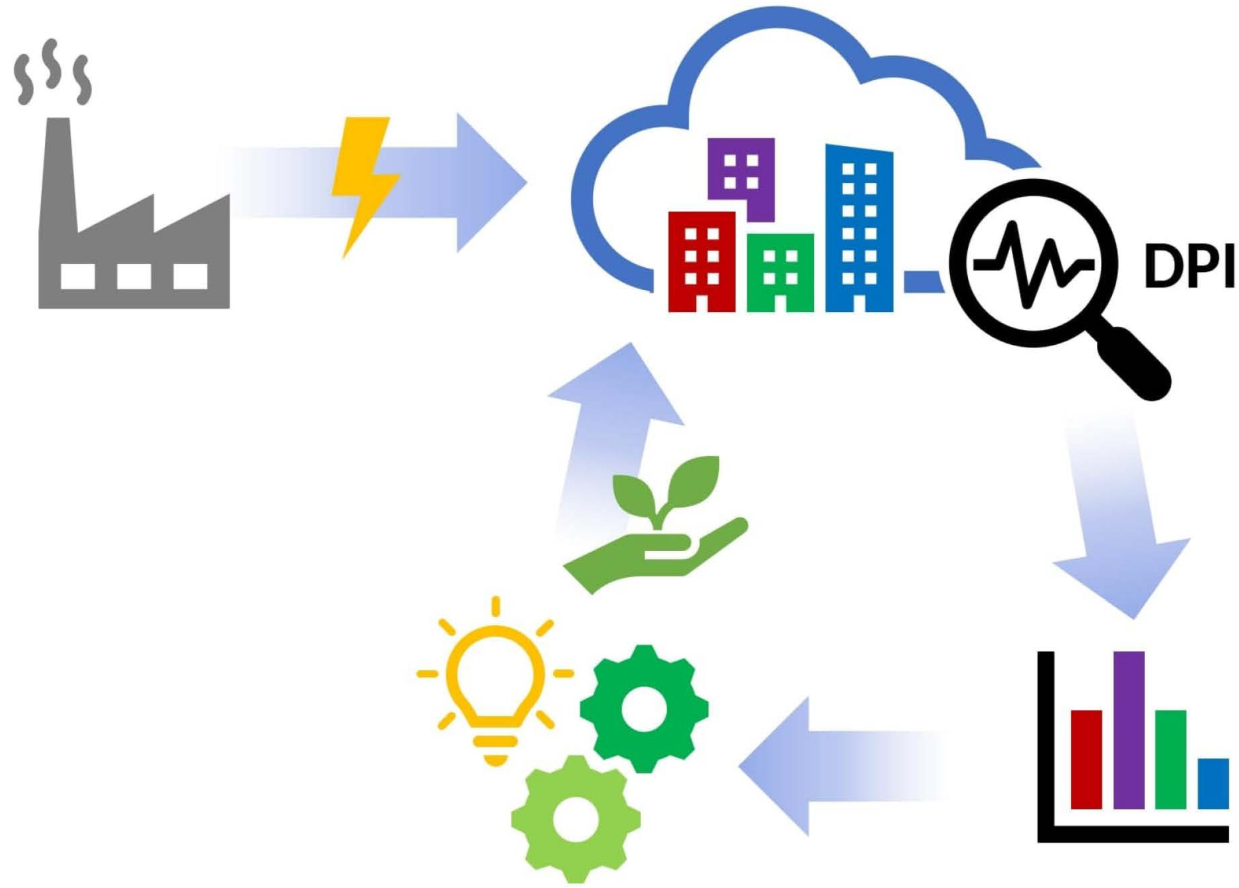

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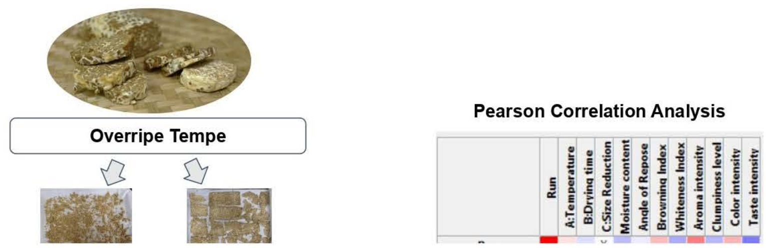

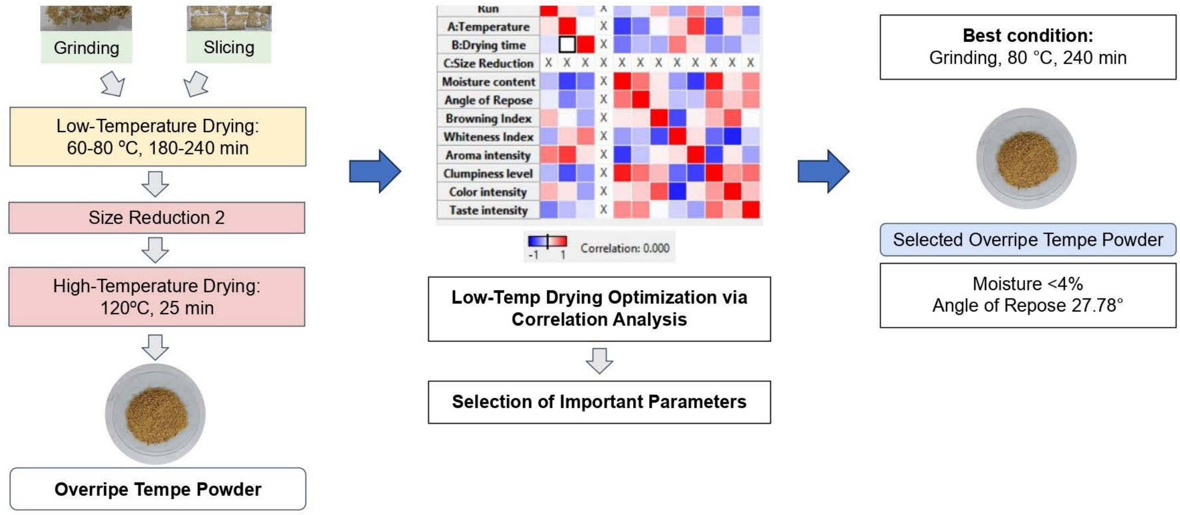

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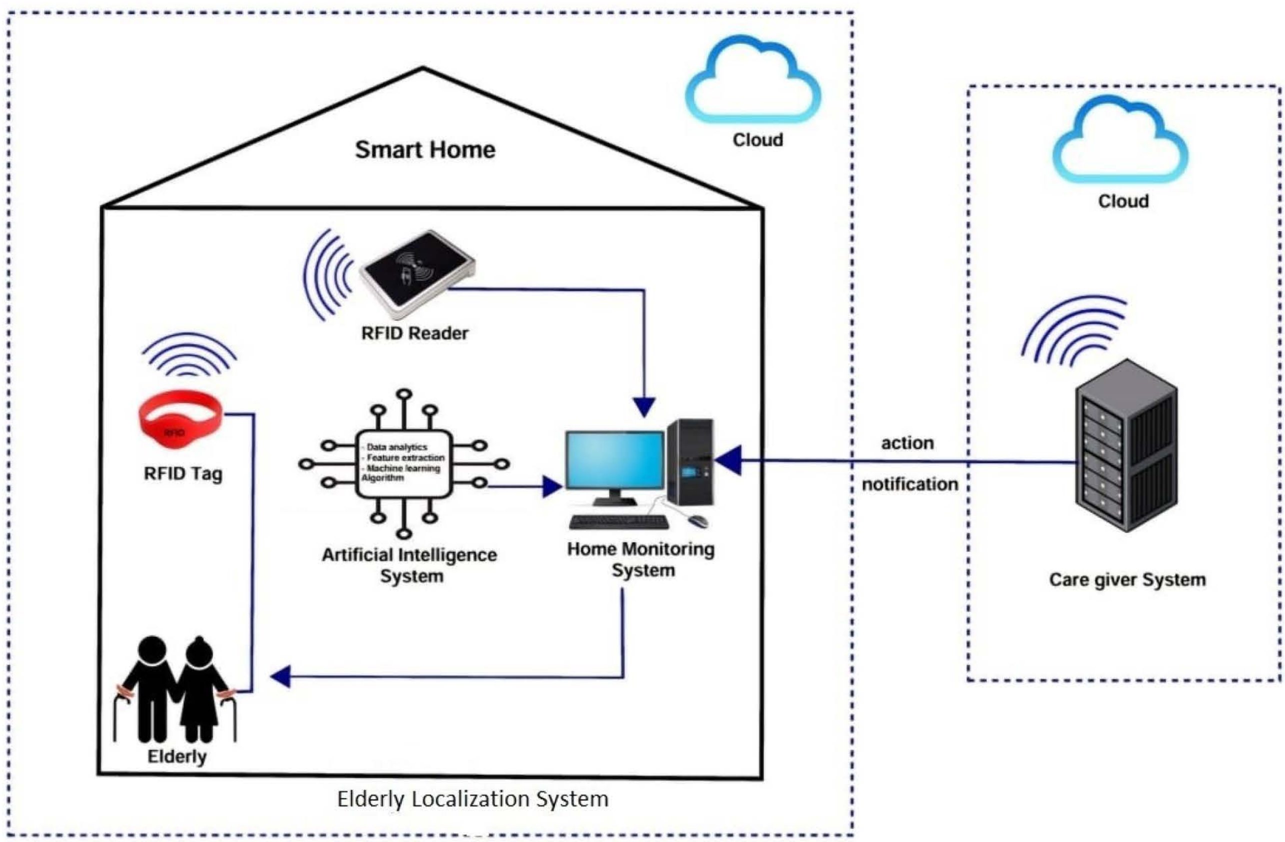

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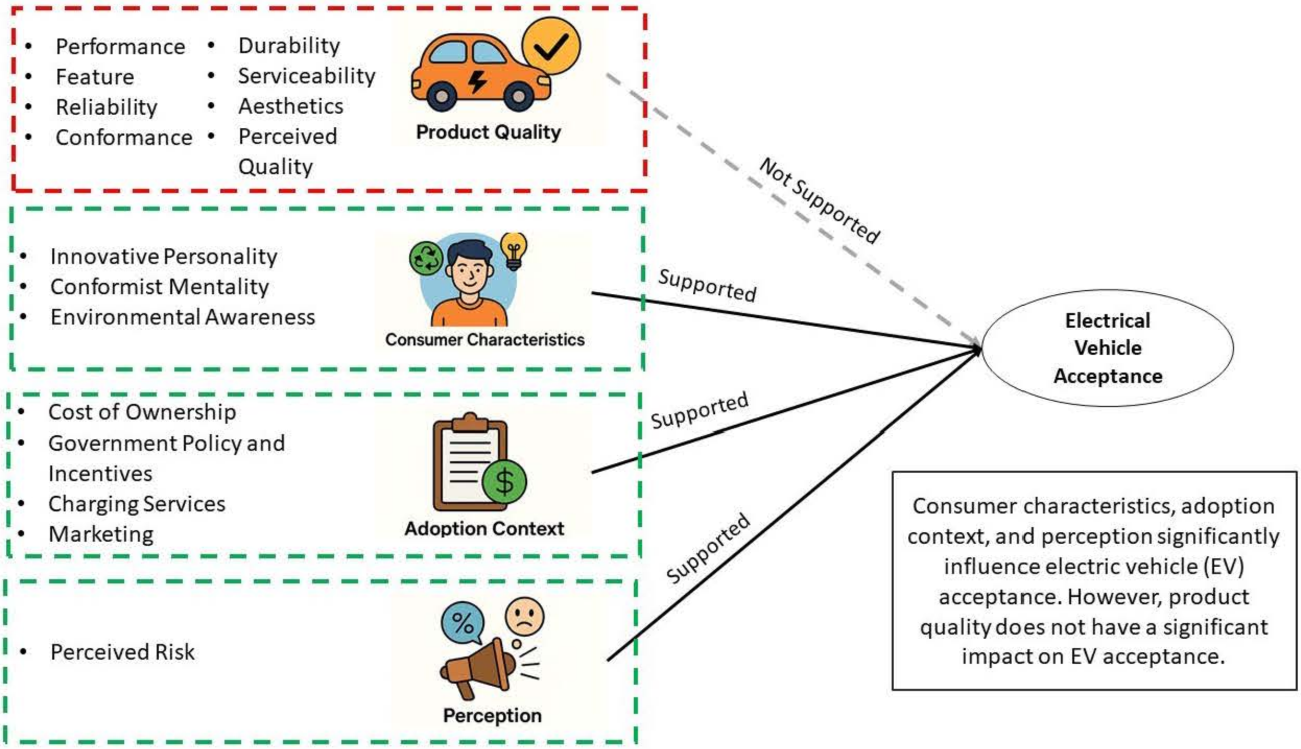

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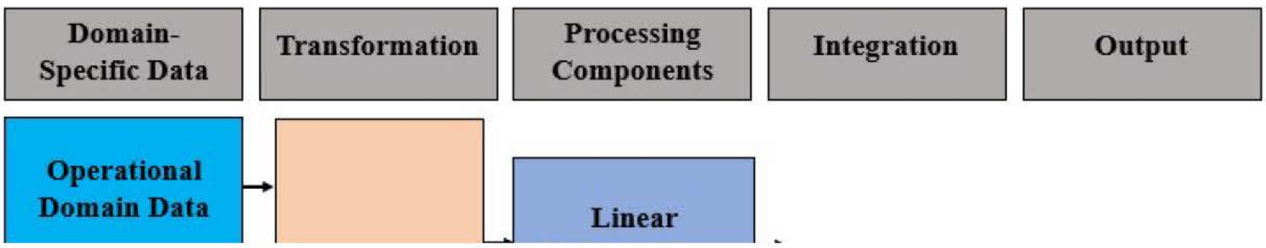

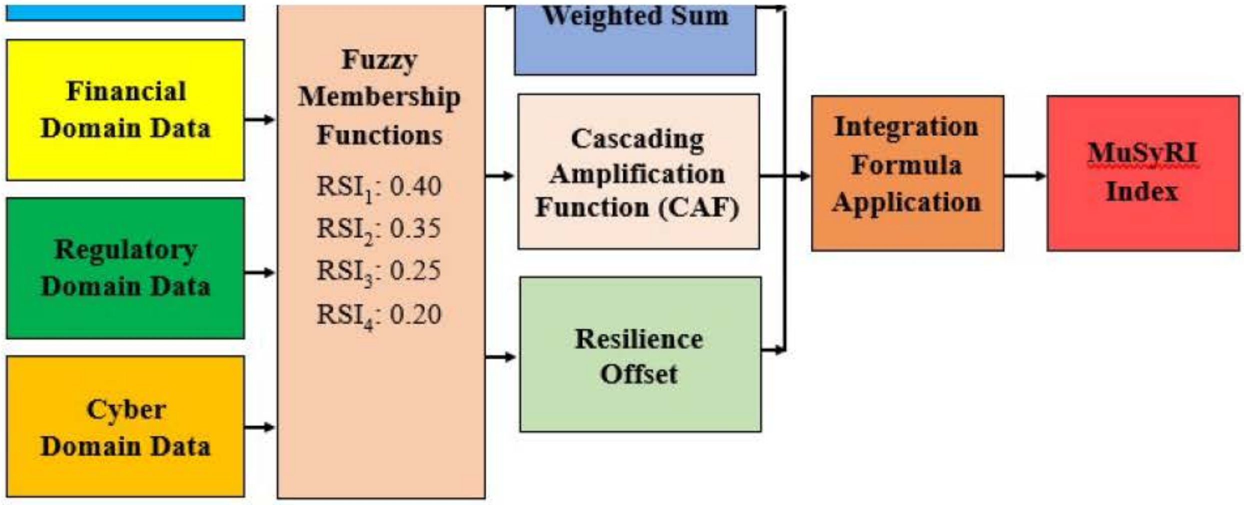

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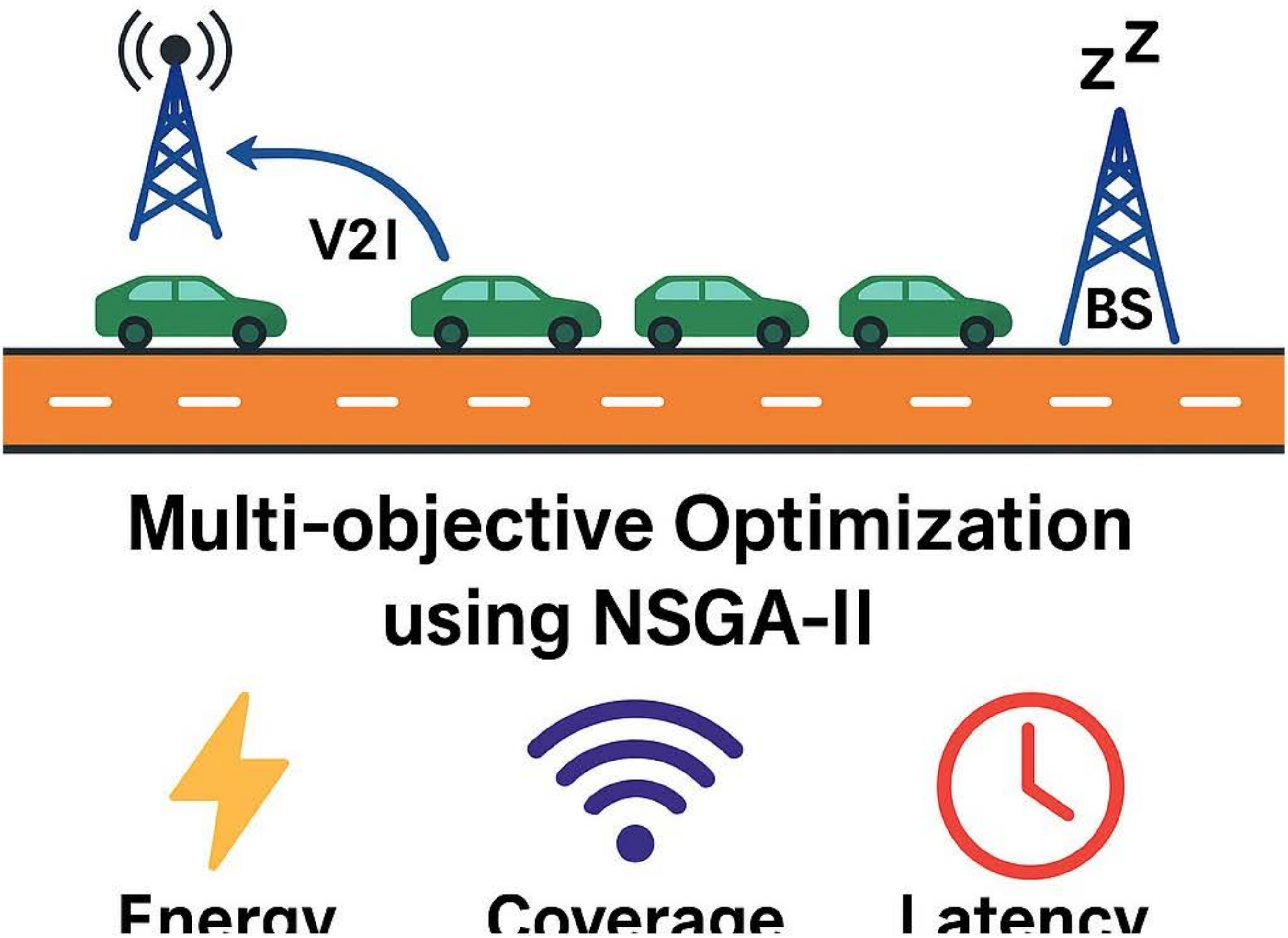

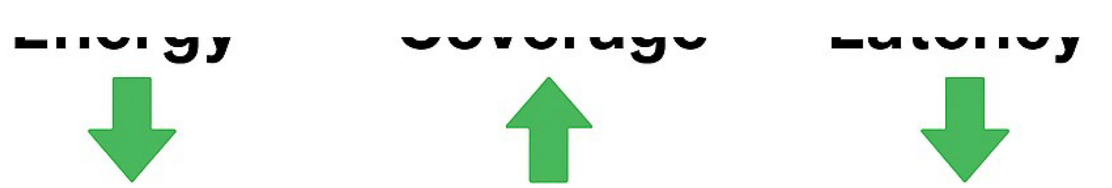

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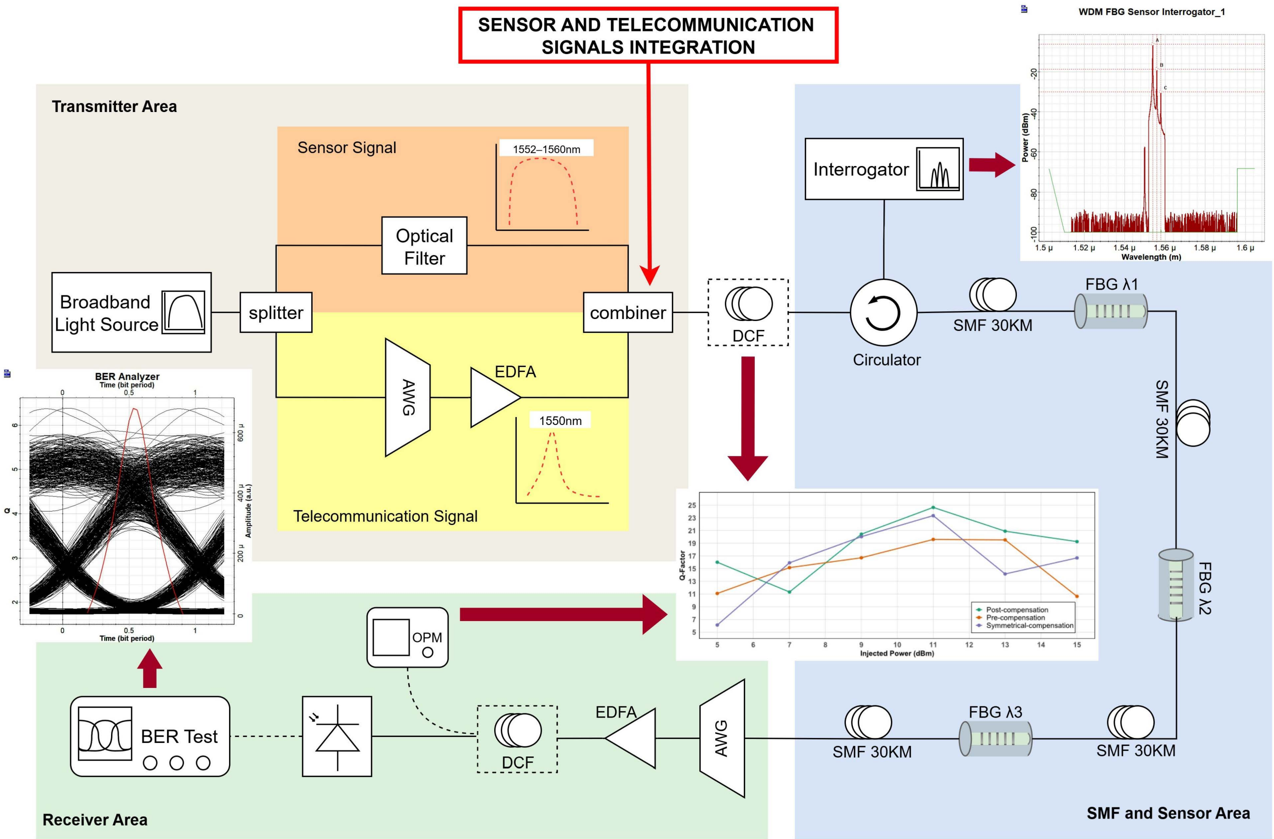

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Publication Date (Online):
Dec 01, 2025
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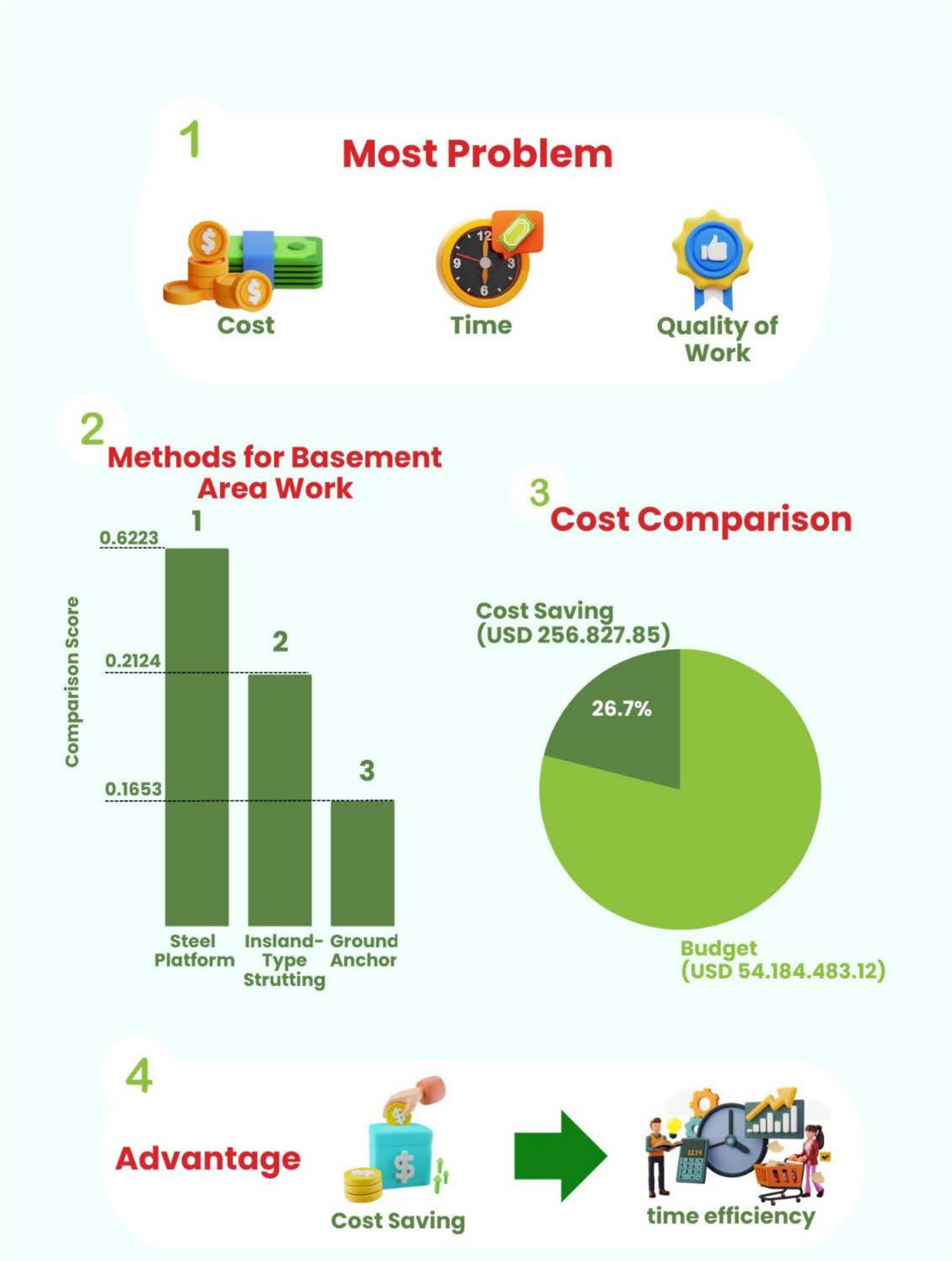

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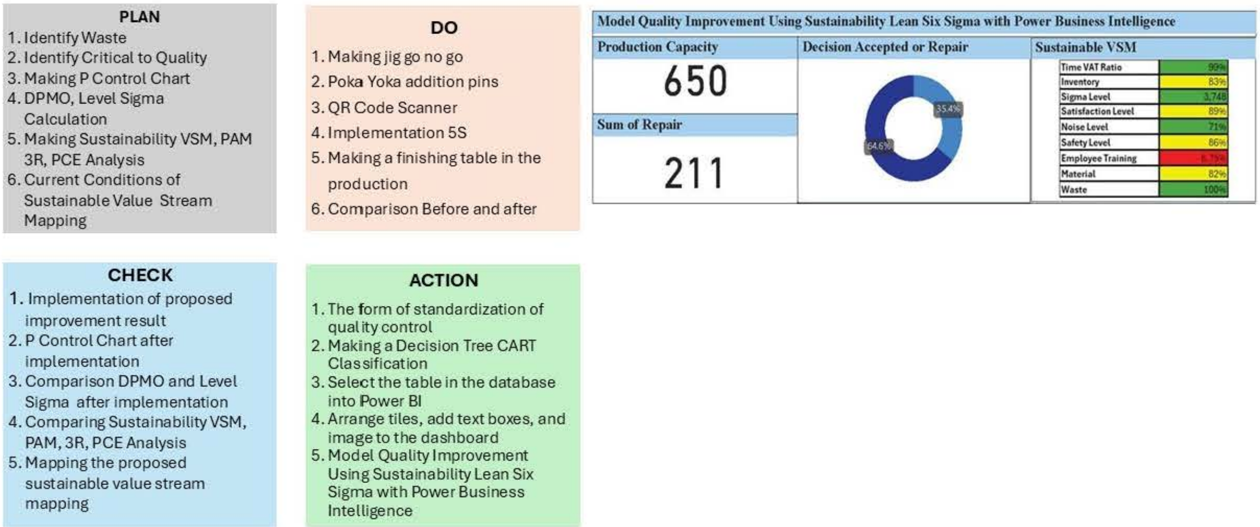

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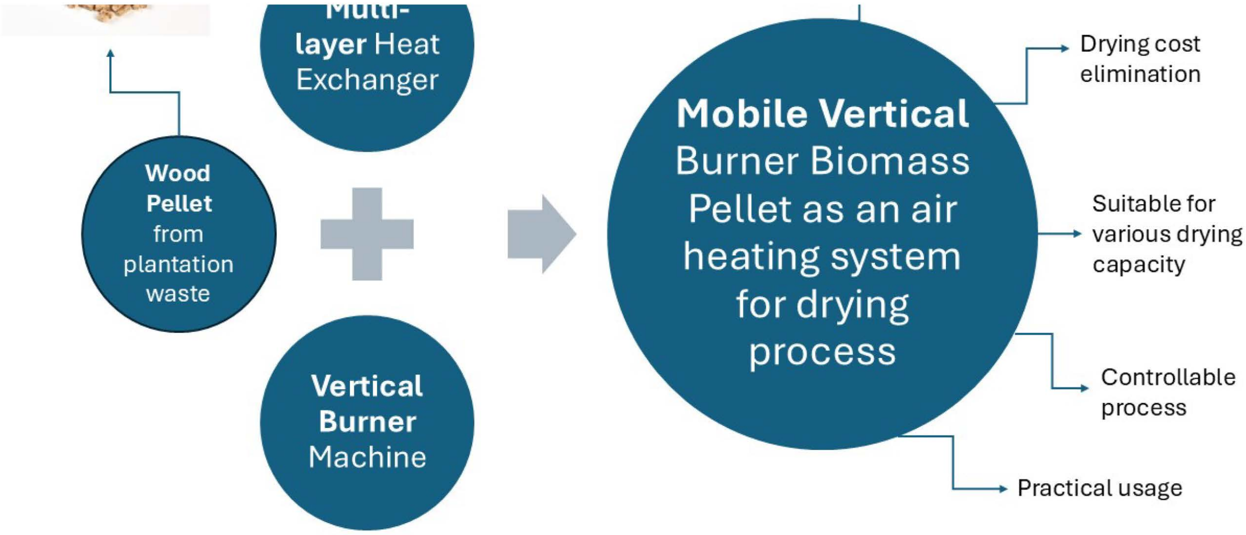

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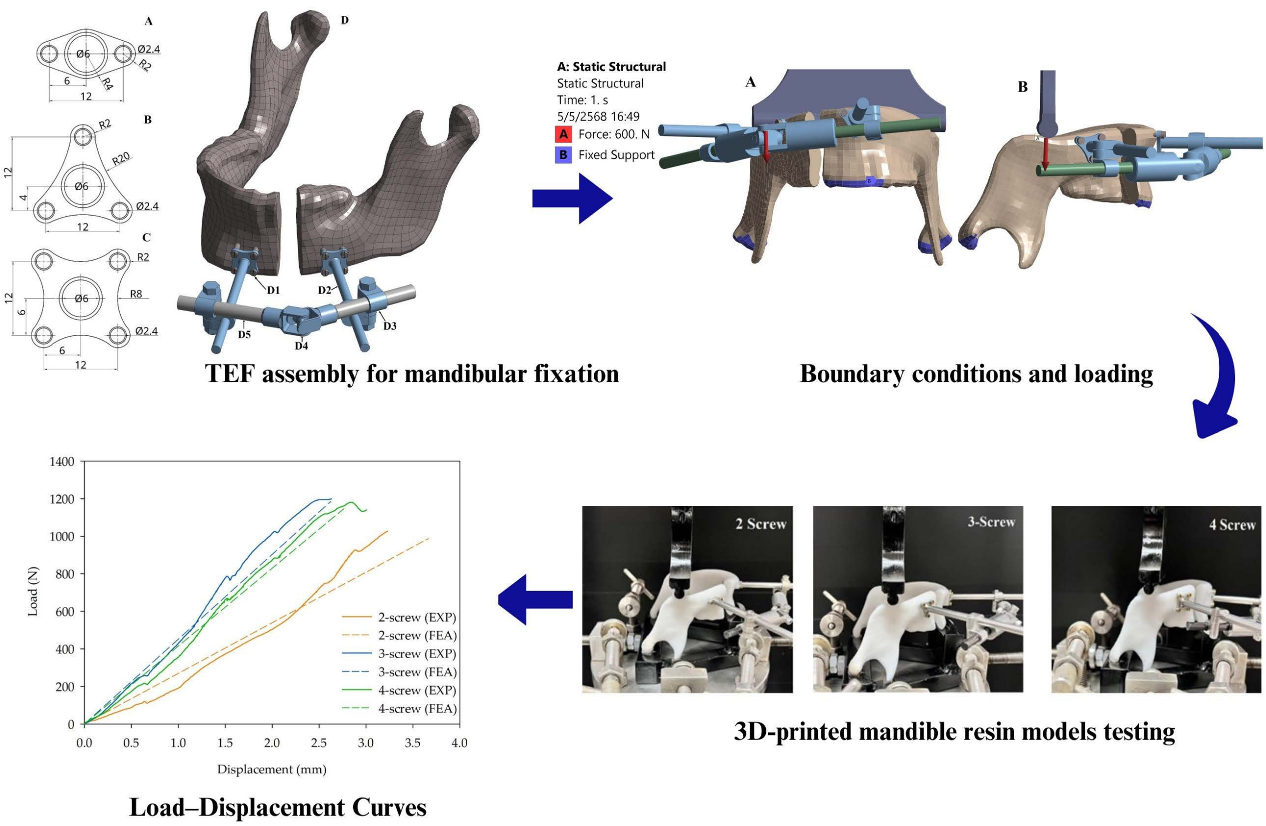

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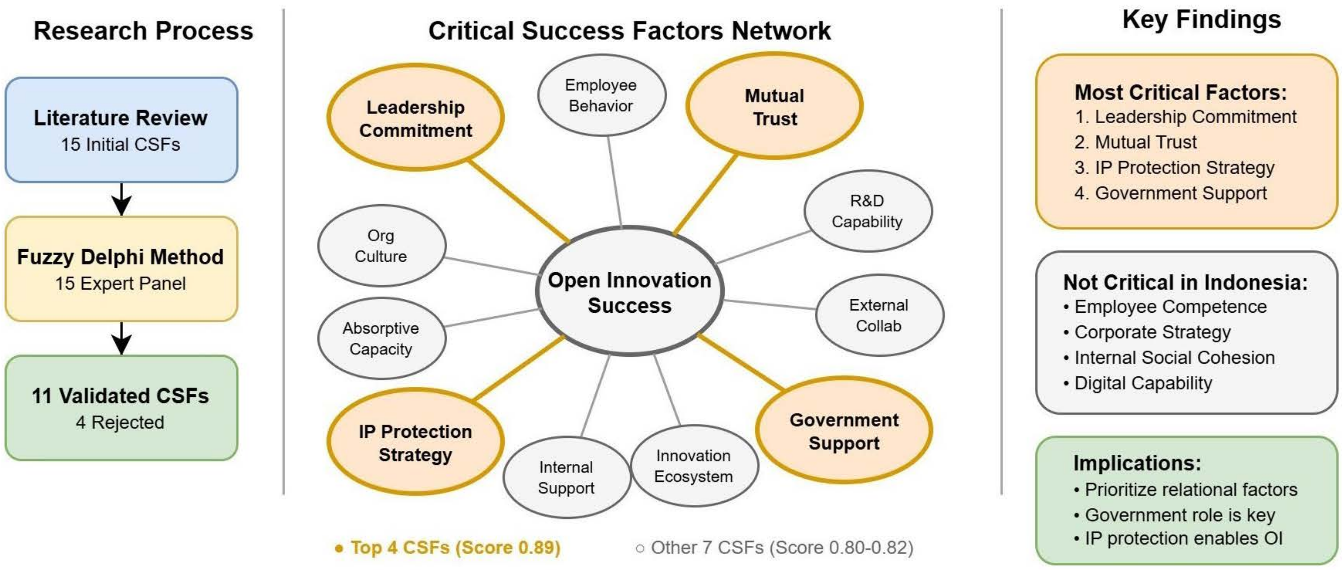

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p-ISSN : 2086-9614 (https://portal.issn.org/resource/ISSN/2086-9614)
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Depok 16424, Indonesia.

INTERNATIONAL JOURNAL OF TECHNOLOGY

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P-ISSN : E-ISSN : 20872100

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