Design Science Research Methodology Concept and Its Application in the Development of Online Community Communication System for Selotapak Village

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***Abstract*—Natural science is a collection of global validated knowledge on objects to understand the characteristics and properties of natural phenomena. The natural science field uses the scientific method as its research method. In further development, humans use this scientific field to meet their daily needs, leading to the emergence of an artificial terminology known as design science. Many design science researchers create Design Science Research Method (DSRM) as an experimental method used in design science research, which came from modification of the scientific research method. Based on the broad utilization of design science to determine the solutions to human problems, many scientific fields have adopted the DSRM approach, such as medical science, pharmacy, socio-technical, management, engineering, education, psychology, etc. This article aims to discuss the concept of DSRM and to illustrate this method's application in developing the Online Community Communication System for Selotapak Village as the research case. Each DSRM phase run in this research was modified to iterate in 2 rounds. The first round aimed to capture problems generally; meanwhile, comprehensive result validation and identification were observed in the second round. Semi-structured interviews, questionnaires distribution, and observation were used in the DSRM iteration phase as research strategies. Several design models were used to depict data, user interface, and processes required, such as Entity Relationship Diagram and Business Process Modeling Notation. The evaluation result shows that all users were satisfied with the application.**

Keywords—design science, design science research method, information system research method, online community communication system.

I. INTRODUCTION

Natural science historically developed during the Renaissance[1], and it focuses on understanding natural phenomena and their interactions with each other [2]. Humans use this scientific knowledge to meet their daily needs and solve logical problems, which further leads to the emergence of design science. In principle, natural science studies reality, while design science creates an inclusive environment that is sustainable and beneficial to humans [2].

According to previous research, Information Systems scientifically help to produce technical applications such as problem-solving in human organizations and management, clearly indicating that this field is a part of design science [2], [3]. The DSRM (Design Science Research Method) as a research approach in design science, has been carried out by various research in Information Systems since 1991 [4]–[7]. Therefore, this research aims to discuss the concept of DSRM and to illustrate this method's application in the development of an online community communication system for Selotapak village as the research case.

The outline of this article is described as follows: Section I contains an introduction explaining the primary goals, section II includes literature research evaluating the history and development of knowledge and methodology, accompanied by an explanation of design science in information systems, section III explains the examples of DSRM application on a case study selected, and Section IV contains the conclusions and closing remarks.

II. LITERATURE RESEARCH

A. History of Natural and Design Science

Natural science is a collection of global validated knowledge on objects for understanding the characteristics and properties of natural phenomena. It is also designed to explain the characteristics, properties, and interactions of innate elements [2]. Many natural phenomena are revealed in natural science, such as the earth's gravity and the universe's heliocentric theories by Isaac Newton and Nicolaus Copernicus, respectively. In addition, the main tasks of natural science are to determine the facts [8], explain complexities, and broaden the scope of understanding [2]. Humans also use this scientific field to meet their needs, leading to the emergence of an artificial terminology known as design science [2], [9]. According to Denyer (2008), this terminology was arguably the knowledge guiding the quest to improve human condition, through the development of realistic problem-solving patterns [8]. In this case, natural science studies reality, while design science creates an inclusive environment that is sustainable and beneficial to humans [2].

Rittel and Webber (1973) also established the notion of "wicked and tame problems" in the field of social policy [10]. A wicked problem emphasizes characteristic values, such as unstable requirements and constraints, complex interactions between sub-components, high flexibility to change designs and artifacts, as well as great dependence on human creativity and socialization to formulate solutions [11]. Meanwhile, the features of the tame problem focused on the description of all necessary related information. Based on these conditions, natural and design science were categorized as tame and wicked problems, respectively [6].

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B. Research Method in Natural and Design Science

In the natural science field, the scientific method is often used to examine nature and answer basic questions on the following, (1) The working patterns of the approach, (2) The next line of action, and (3) The previous, present, and future existence of the approach [12]. Regarding the Oxford English Dictionary, this method has characterized natural science since the 17th century through systematic observation, measurement, experimentation, formulation, testing, and hypothetical modification. The steps involved also included the following, (1) initial observation/research, (2) formation of a hypothesis, (3) hypothetical analysis, (3) hypothetical evaluation, and (4) hypothesis acceptance and rejection [12], [13]. In this condition, any experiment unable to be mathematically/scientifically analyzed is not considered a part of science [12].

Due to the optimal performance of the scientific method on tame problems, its utilization is not completely maximized in design science (wicked problem) [6]. However, a similar core of cognitive processes is observed in both scientific fields [14]. In this case, the scientific method is modified for a design science analytical approach [6], as shown in Fig. 1. This led to the development of DSRM, which comprehensive explanation is highly described in part D. Table 1 provides a summary of the differences between natural and design science.

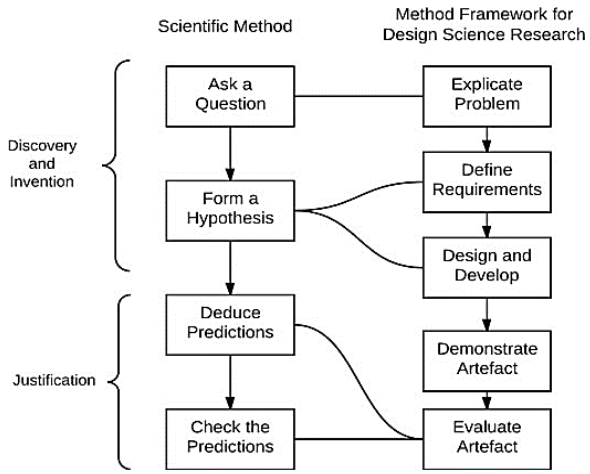

Fig. 1. Scientific Method and DSRM [6].

TABLE I. COMPARISON BETWEEN NATURAL AND DESIGN SCIENCE

	Natural Science	Design Science
Definition	Learn the characteristics and properties of objects and natural phenomena.	Learn the patterns of helping humans solve real-world problems
Objective	Seeking truth, understanding complexity and phenomena, as well as straightening knowledge	Determining solutions to human problems
Related Fields of Science	Biology, Physic, and Chemistry	Medical, Engineering, and Management
Characteristic	Tame Problem	Wicked Problem
Research Method Approach	Scientific Method	DSRM

C. Information System Research

Based on the wide utilization of design science to determine the solutions to human problems, many scientific fields have adopted this DSRM approach, such as medical science, pharmacy, socio-technical, management, engineering, education, psychology, etc. [6], [9], [15]–[17]. The existence of problems in the field motivates the implementation of DSR as well as opportunities to use knowledge in specific ways through deep engagement with these real-life problems [17]. This led to the application of the method on Information Systems (IS), which was pioneered in 1991 and continuously performed until today [3]. In this condition, two paradigms characterized the systematic analysis, namely behavioral and design science. Behavioral science emphasizes the social field, which is part of the natural context. This aims to develop and verify the theories explaining or predicting human or organizational behavior. Meanwhile, the design science paradigm focuses on the development of innovative capabilities to expand the boundaries between humans and organizations in solving existing problems [11]. This proves that the artifact produced by design science are related to the theories generated by the behavioral field.

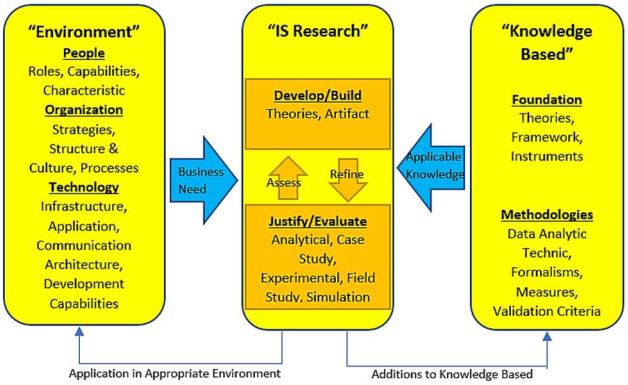

Fig. 2. Information System Experimental Framework [11].

Based on Fig. 2[11], the observed model was used to describe the patterns of understanding, executing, and evaluating the performance of IS analysis. This was achieved by combining the two paradigms within the scientific field, with each model element described as follows:

- Environment: This is the problem space where interesting phenomena and information system materialsare located. In this condition, the existing and non-existing ecosystems of people, organizations/businesses, and technology are often observed.
- IS Research: 2 complimentary phases were carried out to solve problem, namely development and evaluation. Artifacts and theories were developed from design and behavioral science perspectives, respectively. Furthermore, evaluation is conducted through various methods, including analysis, field and case studies, experiments, and simulations. This process helps to identify the errors existing within the analytical developments, i.e., theories and artifacts.
- Knowledge Base: This provides a source of knowledge used in Information Systems research activities. It also contains the foundations and methodologies used as

references and information system stages, respectively.

Experimental accuracy is also achieved when the foundations and methodologies applied are appropriately selected and performed. As artifacts, these analytical contributions are adequately tested when applied to business requirements in an appropriate environment. The results obtained are also observed as new knowledge foundations for future reports.

D. Design Science Research Method in Information Systems

DSRM defines the research process and activity flows for presenting, and conducting design science research [18]. In Information Systems, the DSRM is based on the notion model conducted by Takeda (1990) [4], as shown in Fig. 3.

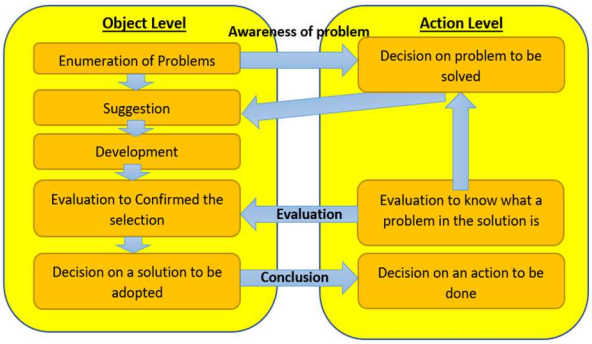

Fig. 3. Takeda's DSRM Model [4].

According to Fig. 3, the model contained the following five sub-processes:

- Awareness of Problem: This involves the identification of problematic activities
- Suggestion: The recommendation of a specific concept to solve a problem
- Development: The enchantment of candidates for a solution
- Evaluation: The assessment of solution candidates fromcomputation, behavioral, and cost perspectives. This cycle is repeated with the occurrence of a new problem.
- Conclusion: This decides the candidate solution to be adopted.

Based on these conditions, the processes of DSRM were also found to have evolved several times [5], with Fig. 4 showing the model provided by Johanesson et al. (2021), which is used as a reference in this research [6].

The analysis of design science also generally emphasized solving the problems encountered by individuals and organizations. This was carried out through the production of an artifact, as a problem-solving technique and new knowledge responsible for theory formation [19]. In this condition, the results obtained were used as a knowledge base for subsequent reports. The types of artifact produced were also observed as constructs, models, frameworks, architectures, design principles, and theories, as well as instantiations [5].

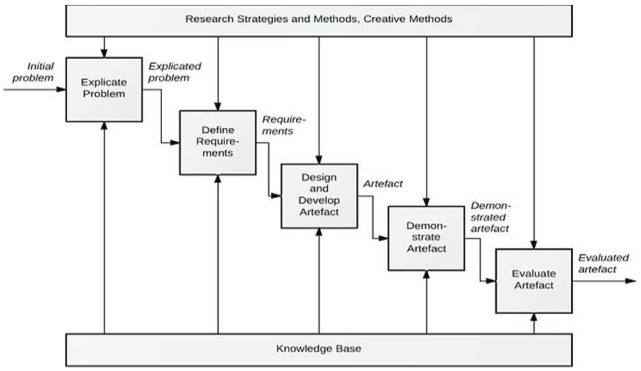

Fig. 4. Design Science Research Method Phase [6].

To adopt appropriately every DSRM steps to produce valid outputs, various strategies and methods were applied creatively. This creative application included Experiments, Surveys, Case Studies, Ethnography, Grounded Theory, Action Research, and Phenomenology. Each of these methods also had its respective advantages and disadvantages for the simultaneous application of the DSRM strategies. Therefore, more validity was expected for the obtained results.

From the analysis of the design science, the results need to be original and have a solid theoretical foundation. Each DSRM stage also needs to emphasize an existing and tested knowledge base, which results were conducted as artifacts, such as theories, institutions, models, frameworks, etc. [6]. In this condition, the newly developed became a knowledge base for subsequent studies, regarding the analysis of the referenced concept [11].

III. Case Study

Based on the development of the Online Community Communication System for Selotapak Village, a case study on the application of DSRM in Information System was carried out by many researchers, such as Hevner et al. (2004) and Peffers et al. (2008) [7], [11]. This was to obtain a better understanding of the DSRM concept. From the creation to the evaluation of the design artifact process, the methodological phases were iterated regarding prior knowledge against potential [6], [20], [21]. This showed that each DSRM step was modified to function in 2 rounds. In this condition, the first round aimed to generally capture problems, with comprehensive result validation and identification observed in the second round. Therefore, this research aims to create a web-based communication system for the village government and the community of Selotapak villagers. According to Everett M. Rogers (1986) [22], four eras of communication were observed, namely the written, print, telecommunications, and interactive media. In this process, the development of technology has presently penetrated rural communities, including the Selotapak village, which is one of the potential tourist settlements in East Java. This requires the media to facilitate communication regarding information distribution, coordination and village problem reports, as well as follow-up between the village government, and the Selotapak community. The results obtained are expected for appropriate service management to the Selotapak village community and tourists.

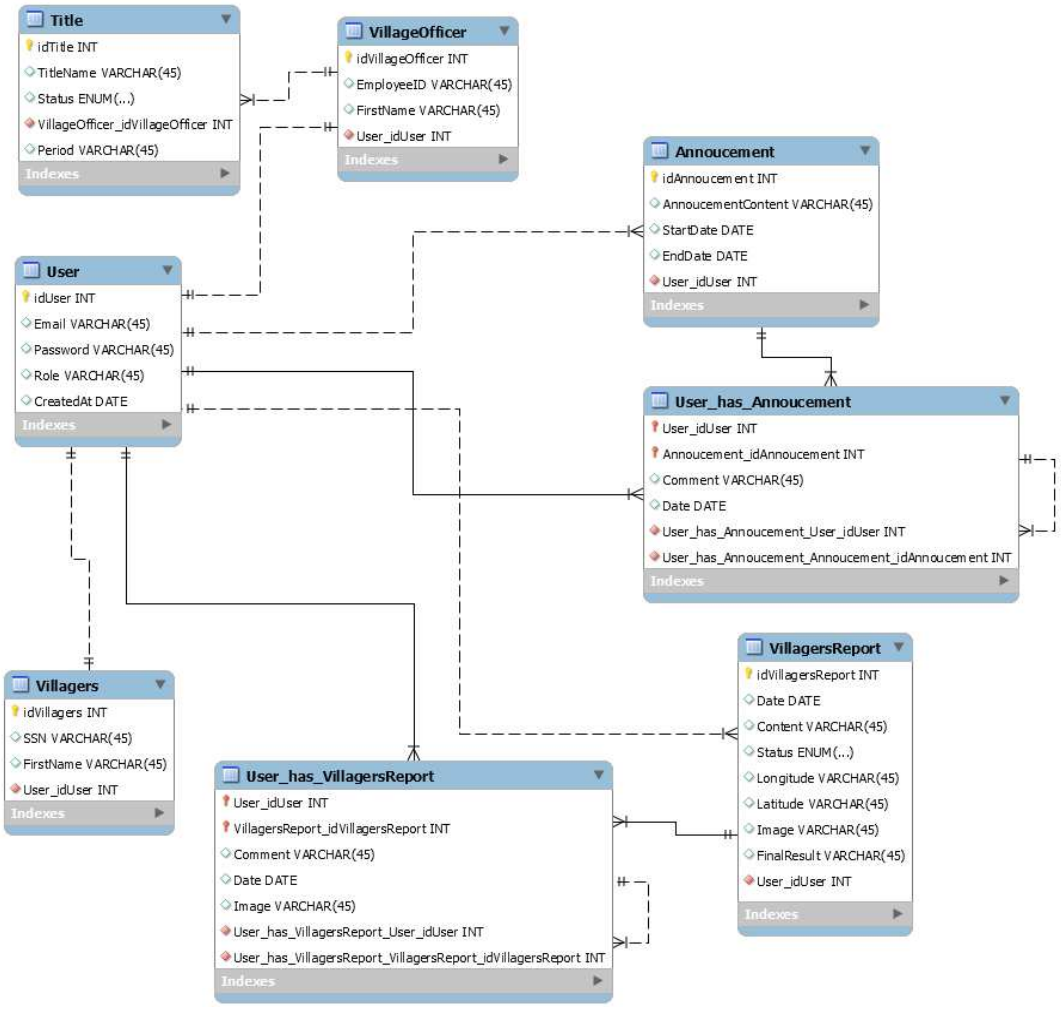

Fig. 5. Entity Relationship Diagram of the system

A. Explicated Problem

Based on the DSRM stage, an Explicated Problem step was considered, where the issues raised as inputs emphasized the development patterns of effective communication, coordination, and village reports, as well as follow-up between the government and the Selotapak community. In this situation, the initial procedure focused on obtaining an understanding of the present communication system and the existing challenges. Subsequently, the second round considered the validation of problems in the communication system occurring in Selotapak Village. Based on the analytical methods, the first round adopted an observation and unstructured interview technique. More comprehensive literature research and semi-structured interviews were carried out in the second category. The results obtained were also used as the definition of problems in the village, which included the following, (1) the difficulty of distributing information to all villagers, (2) the difficulty for villagers to determine information/specific village rules, and (3) the confusion for villagers in reporting the problems related to infrastructure and monitoring.

B. Define Requirement

In this step, the artifact and the requirements were adequately defined. The input in this stage emphasized the output of the previous step regarding the problem definition. From the results, the artifact produced was an instantiation of the Online Community Communication System for Selotapak Village. In the first round, the shape of the artifact was also determined through semi-structured interviews with a comprehensive definition conducted in the second category via a suitable recursive discussion and benchmarking for similar systems [20, 21, 23]. This proved that the direction of the existing village information system was more defined for the unidirectional distribution of information from the government to the villagers. Based on the results, Selotapak Village required a two-way communication system between the government and the community. Besides the ability of the government to provide information services, residents also played an active role in the production of data for many stakeholders. This indicated that the communication between the government and residents was better for mutual synergy toward the development of villages.

C. Design and Develop Artifact

In this stage, an artifact was then designed from three perspectives, namely data, process, and user interface. The RAD (Rapid Application Development) model was also carried out to maximally facilitate the artifact development process while considering the time limit. Moreover, the first and second rounds emphasized the determination and validation of the design from the developer and stakeholder (the user), respectively. Based on the results, all inputs were then recorded and used for the improvement of the design, accompanied by the development of the artifact into an application.

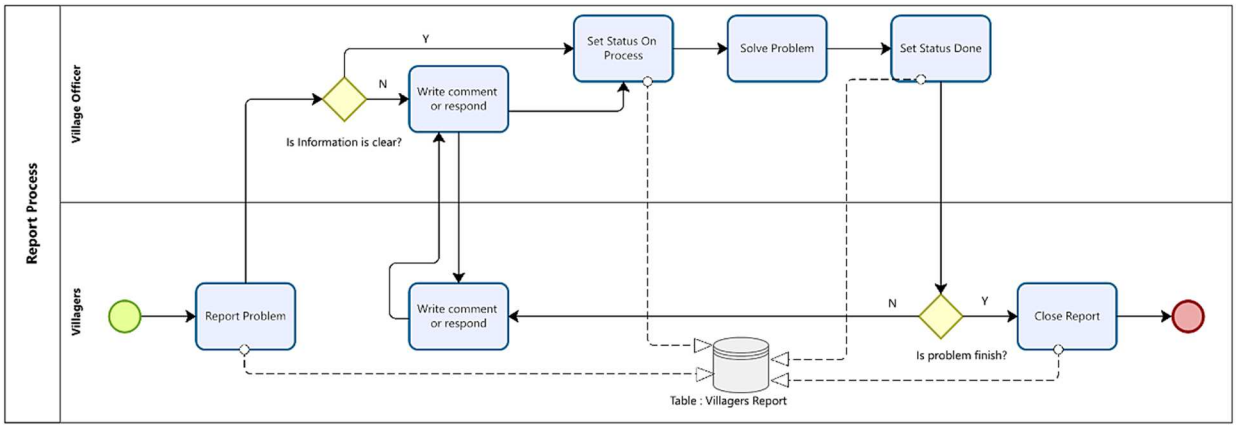

Fig. 6. Business Process Modelling Notation of Report System

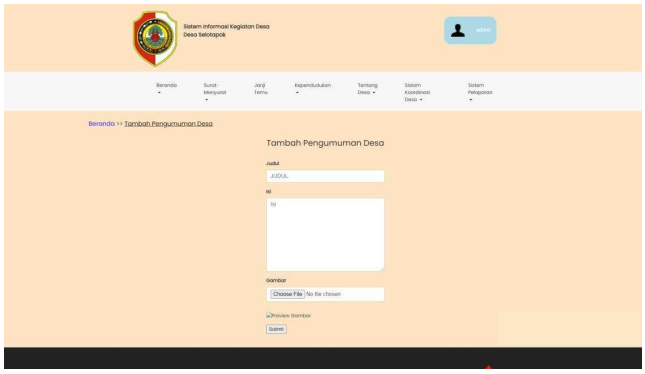

Fig. 7. User Interface Design of Announcement Page

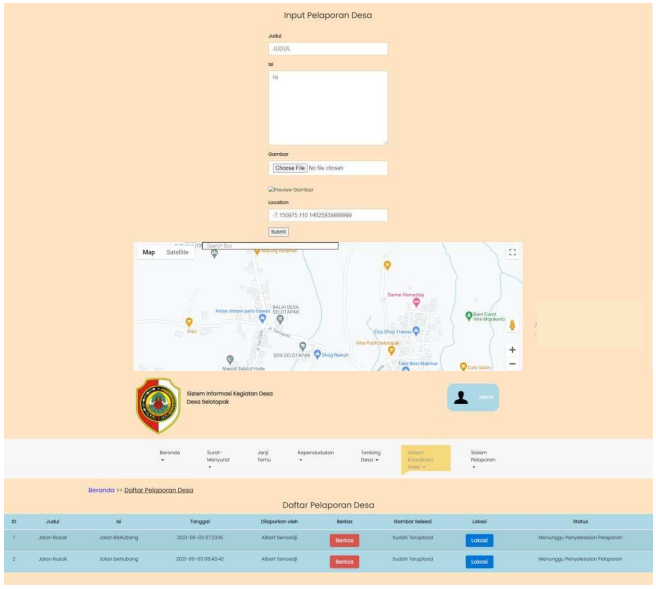

Fig. 8. User Interface Design of Report Page

System design is carried out in 3 perspectives: data design perspective, user interface design perspective, and business process design perspective. Fig. 5 describes the data requirements model for the system. The system has two main communication features. First, the system act as a medium for delivering information from the village officer to the village community, where the villagers and village officers can ask questions or give responses to the information provided, as well. Another main feature is the incident reporting feature in Selotapak Village by villagers. Each incoming problem report is responded to and resolved by certain village officers. Villagers monitor report progress via the system and may determine whether the reports provided can be considered complete or not.

The report system business process is described in Fig. 6. This process comprises two lanes, the villagers and the village officer, and begins with a villager report as an input to the system. The villagers may monitor report progress, and at the end of the process, villagers may determine the status of project completion.

Fig. 7 and Fig. 8 describe the main feature's user interface design of the system. All of the design is then developed using MySQL for database implementation and the Laravell framework to build the overall application.

D. Demonstrate Artifact

This step was carried out to determine whether the developed artifact was able to solve problems and meet users' requirements. Real user involvement in this phase is chosen as design case. Artifact application was running in two rounds. In the first round, the artifact was validated by two stakeholder representatives from the village government and residents in the laboratory environment. During the second round, the artifact was implemented in the real environment to be used by more system stakeholders to get more responses.

E. Artifact Evaluation

To assess the artifact several activities were carried out, including (1) The determination of the evaluation context, (2) Strategy selection, and (3) Evaluation performance. In this case, the context emphasized the patterns by which the system appropriately solved the existing problems. The formative evaluation approach is carried out along with the selection of the software process model using RAD. With RAD, artifacts are evaluated from the development phase as part of an iterative process. Furthermore, an ex-post strategy was selected in the first round, to obtain adequate feedback from the artifact users. This strategy emphasized an interview and questionnaire distribution survey, which results were adequately utilized in the second round to improve the performance of the artifact.

The feedback from artifact users came from 1 urban village head, 3 urban village officers, 33 villagers, showing that all users were satisfied with the features provided. Overall feedback results from urban village head and officers showed that 79,9% of artifact users consider this application very helpful, and 20.1% find it helpful. Similar results were obtained from the villagers. The result shows that 52% of artifact users consider that the application features are very helpful, and 49% find it helpful. Fig. 9 shows the evaluation result.

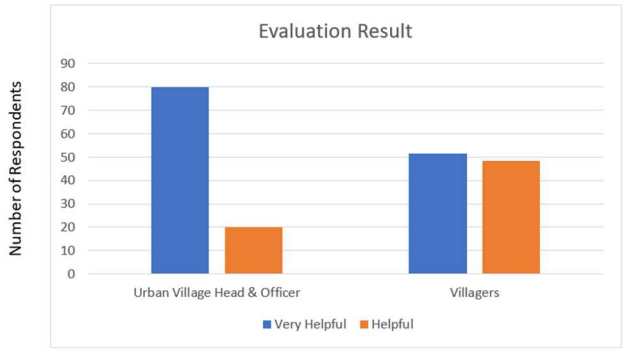

Fig. 9. Evaluation Result

IV. Conclusion

This research aimed to introduce and evaluate the DSRM model with the development of an online community communication system for Selotapak Village being appointed as an application example. This was performed to obtain a better understanding of the model implementation. In this situation, the execution pattern of each model step was also described in the development of artifact. Furthermore, a benchmarking approach was carried out to obtain an overview of the village information system due to being presently applied in many settlements. It was also performed as a trade-off effort from the existing system to generate a new idea expected to solve the communication and information distribution problems in the village. Based on the results, the need for 2-way communication was highly considered. Irrespective of the village government's ability to provide information services, the residents also played an active role in the production of data for many stakeholders. Therefore, the communication between the government and residents was observed to be highly appropriate regarding the mutual synergy to develop villages.

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