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Comparison of Probability Impact Matrix and Fuzzy Logic Methods for Risk Analysis of Rural Infrastructure Projects in Indonesia

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ABSTRACT: Through the provision of facilities and infrastructure in the Village, it can be used as an effort to empower the community to accelerate regional economic development that is effective and robust. In its implementation, infrastructure projects have risks that can have an impact on the sustainability of the project. Therefore the research aims to analyze what are the most influential risk factors in Participatory-Based Rural Infrastructure Projects using the PIM (probability impact matrix) and Fuzzy Logic Methods. This research uses a descriptive method with a qualitative and quantitative approach. The collected data will be analyzed using the Fuzzy Logic method. The results of the identification of risk factors for infrastructure projects were identified as many as 23, but after validating the risk identification for rural infrastructure projects, there were 17 identified risk factors. Based on the results of the analysis using the risk matrix, 17 factors have values that tend to be small and overall are at a moderate level. However, after analysis using the Fuzzy Logic method, the risk factor values varied, and there were 8 risk factors that were at a high level, these risk factors included technological failure, land change, negligent social behavior, bad design, inappropriate materials, inappropriate methods, inappropriate Standard Operating Procedures.

KEYWORDS: Rural Infrastructure Projects, Risks, PIM, Fuzzy Logic

I. INTRODUCTION

Infrastructure development is an important aspect of economic growth. Good infrastructure development will guarantee efficiency, facilitate the movement of goods and services, and increase added value to the economy, as well as being a driving factor for regional productivity. However, in the development of village infrastructure development it should be adjusted to the needs of the community, not the wishes of the community, and agreed with the community participation method. Transparent development planning and community involvement in infrastructure development are fundamental to be carried out in order to minimize deviations and inaccuracies in planned program targets.

Development of rural infrastructure, with the full involvement of the local community in every stage (planning stage up to the operational and maintenance stage). The involvement of rural communities in the development of rural infrastructure will have several impacts, including (a) the quality of the work produced, (b) the continuity of the operation and maintenance of the infrastructure, (c) the ability of the community to build partnerships with various parties, and (d) strengthening the capacity of the community to be able to independently facilitate community activities in its territory [1].

Construction activities are an important element in development. Construction activities have risks that cause various unwanted impacts, including those related to work safety and environmental aspects. The characteristics of construction project activities include: involving a lot of unskilled labor force with relatively low education (non-skilled), having a limited working period, having high work intensity, being multi-disciplinary and using a variety of work equipment (type, technology, capacity and condition)

Risk is the variation in things that may occur naturally or the possibility of an unexpected event occurring which is a threat to property and financial returns due to the hazard that occurs. Risk and quality management is an approach taken to risk by understanding, identifying and evaluating the risks of a project. Risk is a combination of the likelihood or frequency of a hazard occurring and the magnitude of the consequences of that event. Risk assessment is an integrated analysis of the likelihood of an event occurring and its impact in terms of extent as well as in terms of significance. The probability, extent, and significance of an event can be judged either from previous experience or from calculations using probability theory. To manage risk, risk management is needed [2].

Risk management is an important part of the decision-making process in construction, and is now widely accepted as a vital tool in project management [3]. Various risk management techniques have been studied and introduced in various literatures, which include the processes of risk management, risk identification, risk analysis, risk response, and risk monitoring. Even though many previous studies have been carried out and risk management has also been carried out before construction project construction begins, it is unavoidable that risks still occur. Referring to the risk phenomenon that occurs in rural infrastructure construction projects [4].

Risk is a possibility (possibility) of something unexpected happening beforehand, is detrimental and can affect the completion of the project as a whole with regard to time, cost and quality. Risks can occur in all construction projects, risks cannot be improved but risks can be reduced, transferred to other parties and can be controlled, but risks cannot be ignored. So it is important to understand risk and systematically how to analyze, mitigate and control it systematically so that the project objectives in terms of cost, time and quality can be achieved.

Zhang et al (2020) stated that risk is divided into 3 (three) groups, namely a). External risks, namely: political, economic, social and weather related risks. b). Project risks (construction process criteria), namely: risks related to time, cost, quality of work, construction, and technology, and c). Internal risks include: risks related to resources, project members, construction sites, documents and information [4] [5], the three categories above are divided into 2 (two) categories, namely: a). technical risk; concerned with assessing the likelihood that the system embodied in design when built meets performance requirements, and if performance deficiencies occur, how serious those deficiencies are. The technical risks described in this case include risks, construction methods, building construction designs, material availability, quality of work, etc., b). Non-technical risks; is a risk that can directly affect a particular project, the cause of which is an unplanned and unexpected event that results in an unwanted deviation from the project implementation location carried out by external stakeholders (non-contractors). The existence of a clear relationship between risks and external stakeholders distinguishes non-technical risks from technical risks in the project context. In other words, non-technical risks usually come from external stakeholders/environment. In this case, non-technical risks related to financial risks, land acquisition, risks from stakeholders or the government, political, legal, partnership, socio-economic risks, weather risks, and others.

Risk management is a central issue in planning and is a management of all speculation. The risk management function is to identify, measure and organize risks by applying resource coordination to minimize, monitor and control the probability and/or impact of unexpected events [6] [7].

In an organization, risk management is used as a tool for making decisions to increase effectiveness. Risk management standards must be implemented in project organizations to get the best in life and also to achieve high success. To obtain significant risk analysis results, the tools and types of risk must be adjusted. This is of course inseparable from the risk management system that will be used as a reference for analysis [8].

Risk management in projects is an approach to risk, in which this method is carried out by understanding risks, identifying risks and evaluating project risks [9] [10] [11] [12] [13].

Project risk management includes several stages.These stages can be described as follows:

a. Risk management planning, selecting approaches and planning risk management activities for the project;
b. Risk identification, deciding which risks will affect the project and documenting the characteristics of each risk;
c. Qualitative risk analysis, characterizing and analyzing risks and prioritizing their impact on project objectives;
d. Quantitative risk analysis, measuring the likelihood and consequences of risks and estimating their impact on project objectives;
e. Risk management planning, taking steps to increase opportunities and reduce threats to meet project objectives; And
f. Risk monitoring and control, namely monitoring known risks, identifying new risks, mitigating risks, and evaluating the effectiveness of risk reduction throughout the life of the project.

Risk response is a form of the process of developing choices and determining actions to increase opportunities and reduce obstacles to project objectives. In this case there are 4 (four) strategy stages that can be used, namely;

a. Acceptance (Do Nothing),

Risk acceptance is a risk management that only accepts (surrenders) to the risks that occur by not taking any action to control the risks;

b. Transfer

Risk Transfer requires transferring the impact of risk to a third party. This transfer only gives part of the responsibility to the third party without reducing the overall risk impact. Most risk transfer using insurance institutions. For this reason, payment is required as a risk premium to the institution that bears some of the risk. In addition, project contractors can also be used to transfer risk to other parties, for example by using a fixed price system under stable conditions;

c. Reduction (Mitigation),

Taking action to reduce the chance of a risk occurring is better than repairing the damage after the risk has occurred. Risk reduction can be carried out using various techniques, namely: reducing the impact of risks that occur; minimize the possibility of risk occurring; and can be used together, to reduce the likelihood of risk, as well as the impact simultaneously.

d. Avoidance,

Risk avoidance influences changes to project management plans to eliminate the constraints of adverse risks, isolate project objectives from the impact of risks, or delay objectives from harm, such as extending schedules and reducing scope.

There is an approach developed using two important criteria, namely;

a. Likelihood (Probability), is the possibility (Probability) of an unwanted event;
b. Impact (Impact), is the level of influence or impact size (Impact) on other activities, if an unwanted event occurs.

To measure risk, the two criteria are arranged in a risk formula as follows;

$$R = P * I \quad (1)$$

Where:

R = Risk level

P = The probability of the risk occurring

I = The level of impact of risks that occur

The risk analysis process can be carried out using various methods, including the PIM (probability impact matrix) method and the Fuzzy Logic method. [2] [6] [12] [14] [15]. Based on the existing risk formula, the risk level of each identified risk factor can be identified. According to Duijm (2015) [7]. The results of the risk assessment for major hazards can be grouped into 3 (three) areas as can be seen in Figure 1

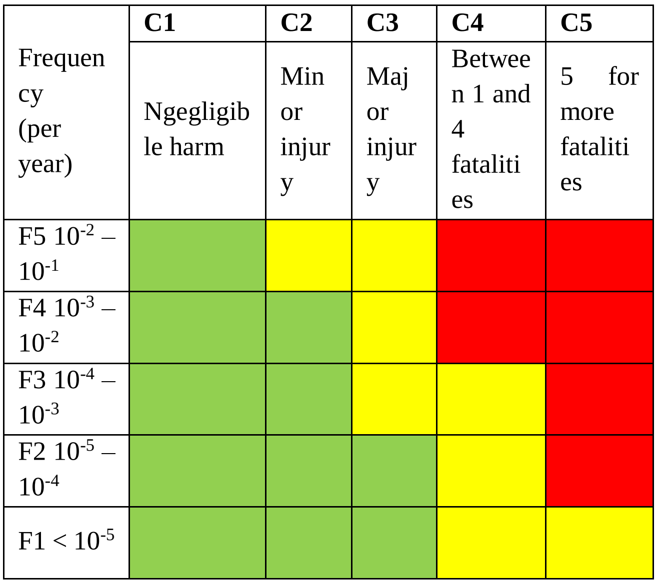

Figure 1. Threshold of project risk levels

So the purpose of this research is to analyze the risks of rural infrastructure projects using PIM and fuzzy logic

II. RESEARCH METHODS

In this study the method to be used is to use a descriptive approach. In general, the methodology used is to combine qualitative research with quantitative research using case studies and survey approaches.

The respondent design used in this study is the permanent respondent design, because the respondents who were formed follow certain rules and do not change during the withdrawal process. The fixed respondent design chosen in this study was the cluster sampling method, namely the technique of selecting a respondent from a group of small units or clusters. The cluster sampling technique used is two stage cluster sampling.

The data used in this research comes from 2 (two) data, namely a). Secondary data, namely data - data obtained indirectly including literature studies based on the results of previous research that has been published or data - data obtained from various other relevant sources. b). Primary data, namely data obtained directly. In this case to obtain primary data is done by collecting data based on respondents' answers to the questionnaire. In order to compile a questionnaire, general preparation steps are needed, namely; a). Operationalize the research variables into the relevant indicators, b). Identify each indicator to the relevant sub-indicators, c). Describe each indicator or sub-indicator in the form of questions, d). Evaluate the accuracy of the content and language of the questionnaire, e). Try out the questionnaire on a group of people who have the same characteristics as the respondent or directly to the respondent concerned.

The instruments used for risk assessment in this study were carried out using the risk calculation formula obtained from the probability and impact relationship using a Likert scale table reference 1 to 5, and analyzed using the PIM and Fuzzy Logic methods

III. RESULTS AND DISCUSSION

The initial stage in the risk management process is risk identification which is a systematic and continuous process in understanding, identifying, classifying potential project-related risks. In risk identification, Grimsey dan Lewis (2002) [16] states that there are at least nine risks faced in infrastructure projects, namely: (1) technical risks; (2) construction risk; (3) operational risk; (4) income risk; (5) financial risk; (6) risk of force majeure; (7) political risk; (8) environmental risk; (9) project failure Research on the risk allocation of PPP projects has been conducted by Tong-yin et al (2011) by evaluating the main risks in urban rail development projects in China [12].

The main risks include: (1) macro environmental risk; (2) economic risk; (3) legal risk; (4) construction risk; and (5) operational risk. Nur Wulan (2005, in Abednego, 2006) classifies risks to road construction projects in Indonesia into 7 categories including: (1) political risk; (2) construction risk; (3) operation and maintenance risks; (4) contract risk; (5) income risk; (6) financial risk; and (7) force majeure risk [4].

Another study conducted by Bing et al (2005) identified risks in PPP projects in the United Kingdom and classified risks into three levels, namely the macro level, the meso level, and the micro level. Research conducted by Bing et al (2005) also discusses risk allocation strategies. Risks allocated to the government include political risk, land acquisition risk, risk of making wrong decisions by the government, risk of nationalization, and risk of unstable government [10]. The risks that must be allocated to the private sector include the risk of changes in tax, design risk, inflation risk, financial risk, risk of changes in demand. The risk of force majeure and the risk of changing policies is a risk that must be shared between the government and the private sector.

Shen et al (2006) have identified 13 risk categories that can affect performance in the Hong Kong Disneyland Theme Park project. In the project, the risks allocated to the government are related to land acquisition risks, legal and policy risks, and the presence of inexperienced private partners. The private party bears the risk of construction, operation and industrial action. Development risk, risk of changing market conditions, financial risk, environmental risk, and force majeure are risks that must be shared between the government and the private sector [17].

A risk allocation mechanism has been proposed by Xu et al (2011) to assist the public and private sector to achieve a more equitable allocation and reduce contracting time and costs. Xu et al identified the risks of 9 projects with PPP schemes in China. The risks allocated to the government are political risk, legal risk, credit risk and risk of lack of infrastructure support, while the private sector bears the technical risk. The risks that must be shared between the government and the private sector are the risk of inflation, the risk of changes in market conditions, and the risk of product prices. The other three risks depend on the specific circumstances of the project, namely the risk of changes in market demand, contract risk and financial risk [13].

Based on the results of the identification of risk factors in infrastructure projects, this research is continued with data validation of rural infrastructure risk factors as shown in table 1.

Table 1. Risk Allocation Mapping in Rural Infrastructure Projects

No	Risk Factors
1	Unstable economy
2	Policy changes
3	Technology failure
4	No compensation for health and safety
5	Incompetent human resources
6	Inappropriate environmental safeguards
7	No job opportunities
8	Poor public communication
9	Land change
10	No conservation efforts
11	Inattentive social behavior
12	Poor design
13	Incompatible materials
14	Inappropriate method
15	Inappropriate Standard Operating Procedures
16	Bad contractor experience
17	Technical problem

(**Source:** Validation Results, 2023)

The data that has been presented based on the identification results as listed in table 1 was analyzed using the risk matrix guidelines. The results of the analysis of this stage are presented in table 2 below:

Table 2. Risk Factor Value Based on the PIM method

No	Risk Factors	P	I	***Probability impact matrix***	
				R	**Lv**
1	Unstable economy	3	3	**9**	**M**
2	Policy changes	2	3	**6**	**M**
3	Technology failure	3	4	**12**	**M**
4	No compensation for health and safety	3	2	**6**	**M**
5	Incompetent human resources	3	3	**9**	**M**
6	Inappropriate environmental safeguards	3	3	**9**	**M**
7	No job opportunities	3	2	**6**	**M**
8	Poor public communication	3	3	**9**	**M**
9	Land change	3	4	**12**	**M**
10	No conservation efforts	3	2	**6**	**M**
11	Inattentive social behavior	3	4	**12**	**M**
12	Poor design	3	4	**12**	**M**
13	Incompatible materials	3	4	**12**	**M**
14	Inappropriate method	3	4	**12**	**M**
15	Inappropriate Standard Operating Procedures	3	4	**12**	**M**
16	Bad contractor experience	3	4	**12**	**M**
17	Technical problem	3	4	**12**	**M**

(**Source:** Analysis Results, 2023)

From table 2 it can be explained that there are 17 risk factors analyzed based on the risk matrix with the value of each risk, namely an unstable economy of 9 with an M level (medium), policy changes with a value of 6 with a medium level, technology failure with a value of 12 at a medium level , no compensation for health and safety with a score of 6 at a moderate level, incompetent human resources 9 at a moderate level, environmental protection efforts that are not in accordance with a score of 9 at a moderate level, no job opportunities with a score of 6 at a moderate level.
Communication to the public is poor with a score of 6 at a moderate level, land use change with a score of 9 at a moderate level, no conservation efforts with a score of 6 at a moderate level, negligent social behavior with a score of 12 at a moderate level, poor design with a value of 12 at the level moderate, materials that do not comply with a moderate level of 12, methods that do not comply with a moderate level of 12, SOPs that do not comply with a moderate level of 12, poor contractor experience with a moderate level of 12, technical errors with a 12 at moderate level.
The risk analysis in this study is continued with the fuzzy logic method with the process as shown in Figure 2 and the results are presented in Table 3.

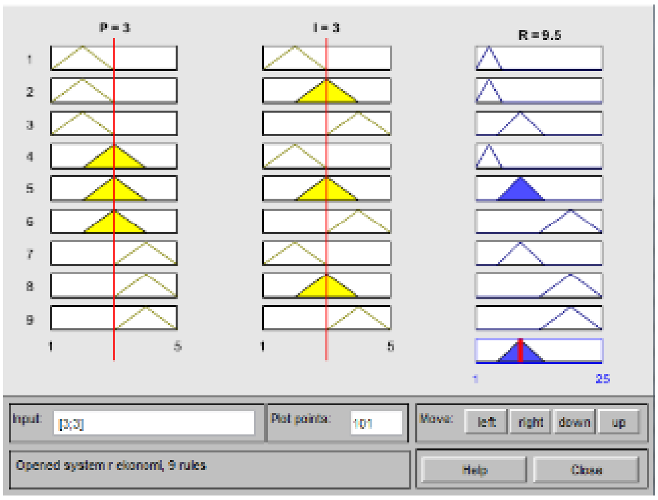

Figure 2. The risk analysis simulation process uses fuzzy logic

Figure 2 is an example of one of the calculations of the risk value, in Figure 2 it is exemplified by the economic risk factor with an input probability value of 3 and an impact of 3 and then a risk value of 9.5 is obtained.

Table 3. Risk Factor Value Based on fuzzy logic

No	Risk Factors	P	I	*Fuzzy*	
				R	**Lv**
1	Unstable economy	3	3	**9.5**	**M**
2	Policy changes	2	3	**3.5**	**M**
3	Technology failure	3	4	**19**	**H**
4	No compensation for health and safety	3	2	**3.5**	**M**
5	Incompetent human resources	3	3	**9.5**	**M**
6	Inappropriate environmental safeguards	3	3	**9.5**	**M**
7	No job opportunities	3	2	**3.5**	**M**
8	Poor public communication	3	3	**9.5**	**M**
9	Land change	3	4	**19**	**H**
10	No conservation efforts	3	2	**3.5**	**S**
11	Inattentive social behavior	3	4	**19**	**H**
12	Poor design	3	4	**19**	**H**
13	Incompatible materials	3	4	**19**	**H**
14	Inappropriate method	3	4	**19**	**H**
15	Inappropriate Standard Operating Procedures (SOP)	3	4	**19**	**H**
16	Bad contractor experience	3	4	**19**	**H**
17	Technical problem	3	4	**19**	**H**

(**Source:** Analysis Results, 2023)

From table 3 it can be explained that there are 17 risk factors analyzed based on fuzzy logic with the value of each risk, namely an unstable economy of 9.5 with a level M (medium), policy changes with a value of 3.5 with a medium level, technology failure with a value of 12 at a medium level , No compensation for health and safety with a score of 19 at a high level (H), Incompetent human resources 15.5 at a moderate level, Environmental safeguards that do not comply with a score of 15.5 at a moderate level, No employment opportunities with a score of 3.5 at medium level, Poor public communication with a moderate level of 9.5, Land change scored 19 in a high level, No conservation efforts scored 19 in a high level, Social negligent behavior with a high level of 19, Poor design with a score 19 at a high level, Materials that do not match the value of 19 at a high level, Methods that do not match the value of 19 at a high level, SOPs that do not match the value of 19 at a high level, Bad contractor experience with a score of 19 at a high level, Mistakes Technical with a score of 19 at a high level.

IV. CONCLUSION

The results of the identification of risk factors for infrastructure projects were identified as many as 23, but after validating the risk identification for rural infrastructure projects, there were 17 identified risk factors. Based on the results of the analysis using the probability impact matrix, 17 factors have values that tend to be small and overall are at a moderate level. However, after an analysis using the fuzzy logic method, the risk factor values varied, and there were 8 risk factors that were at a high level, these risk factors included technological failure, land change, negligent social behavior, bad design, inappropriate materials, inappropriate methods, inappropriate standard operating procedures, poor contractor experience and technical errors.

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REFERENCES

1. Andi, "Pembangunan Infrastruktur Perdesaan Dengan Pelibatan," Jurnal SMARTek, vol. 7, no. 4, pp. 292 - 300, 2009.
2. N. N. Rodhi, "Risk Analysis of Surabaya–Bojonegoro Highway Improvement," Civilla: Jurnal Teknik Sipil Universitas Islam, vol. 7, no. 1, pp. 57-64, 2022.
3. N. N. Rodhi, I. P. A. Wiguna and N. Anwar, "DISASTER RISK MITIGATION OF OIL AND GAS PIPELINES PROJECT IN JAVA ISLAND INDONESIA," ARPN Journal of Engineering and Applied Sciences, vol. 14, no. 24, pp. 4160 - 4163, 2019.
4. M. Abednego and S. Ogunlana, "Good Project Governance for Proper Risk Allocation in Public – Private Partnership in Indonesia," International Journal of Project Management, vol. 24, pp. 622 - 634, 2006.
5. S. Zolfagharian, M. Nourbakhsh, J. Irizarry, A. Ressang and M. Gheisari, "Environmental Impacts Assessment on Construction Sites," in Construction Research Congress , 2012.
6. S. Gohar, K. M, J. M. P and J. A. A. S, "Construction Projects Risk Assessment Based On Fuzzy AHP," in student conference on research and development (SCOReD 2009), UPM Serdang., 2009.
7. N. J. Duijm, "Recommendations on the use and design of risk matrices," Safety Science, 2015.
8. N. N. Rodhi, J. Utomo and W. Agung, "KAJIAN RISIKO PENGGUNAAN SUMBER DAYA AIR BERBASIS PARADIGMA BOTTOM-UP APPROACH (Studi Kasus Wilayah Eksplorasi Banyu Urip – Bojonegoro)," Universitas Diponegoro, Semarang, 2012.
9. M. Labombang, "Manajemen Risiko Dalam Proyek Konstruksi," Jurnal SMARTek, vol. 9, no. 1, p. 39 – 46, 2011.
10. L. Bing, A. Akintoye, P. Edwards and H. C, "The Allocation of Risk in PPP/PFI Construction Project in The UK," nternational Journal of Project Management, vol. 23, no. 25 - 35, 2005.
11. S. Mojtahedi, S. Mousavi and A. Makoui, "Risk Identification and Analysis Concurrently: Group Decision Making Approach," in Proceedings of the 2008 IEEE, 2008.
12. H. Tong-yin, H. Wei and S. Ying-hua, "Risk Evaluation of Public-Private Partnership Projects of Urban Rail Transit Based on Fuzzy Comprehensive Evaluation Method," in Proceeding of the2011 International Conference on Management and Service Science, 2011.
13. Y. Xu, Y. Yang, A. Chan, J. Yeung and H. Cheng, "Identification and Allocation of Risks Associated with PPP Water Projects in China," International Journal of Strategic Property Management, vol. 15, no. 3, pp. 275 - 294, 2011.
14. G. Dag and M. Bagriyanik, "he Effect of Different Fuzzy Membership Function Forms on Controlling Loop Flows," in IEEE, 2009.
15. N. N. Rodhi, "Model Analisis Risiko Proyek Jaringan Pipa Migas Onshore Untuk Sustainable Construction Di Pulau Jawa," ITS Surabaya, Surabaya, 2021.
16. D. Grimsey and M. Lewis, "Evaluating The Risks of Public Private Partnership for Infrastructure Projects," International Journal of Project Management, vol. 20, no. 2, pp. 107 - 118, 2001.
17. L. Shen, A. Platten and X. Deng, "Role of Public Private Partnership to Manage Risks in Public Sector Projects in Hong Kong," International Journal of Project Management, pp. 587-594, 2006.
18. M. Zhang, M. Zhu and X. Zhao, "Recognition of High-Risk Scenarios in Building Construction Based on Image Semantics," Journal of Computing in Civil Engineering, vol. 34, no. 4, 2020.