Risk Analysis of the 150 kV Overhead Line and Cable Construction Projects of Kariangau Substation Toward GIS 4 in The Nusantara Capital

Lutfi Mustakim[1], A. A. B. Dinariyana[2]
[1,2]Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
Email: lutfi.mustakim10@gmail.com

Abstract

The development of Nusantara Capital (IKN) was legalized based on Law No. 3 of 2022 on State Capital (UU IKN). One of PLN's projects in IKN is the construction of a 150 kV overhead transmission line and cable from the Kariangau Substation (GI) to Gas Insulated Switchgear (GIS) 4 IKN. This project has challenges related to the large investment value and complexity, so a comprehensive risk analysis is needed to ensure the success of the project. This research is essential, because based on the data, based on data, 8 out of 10 PLN projects in Kalimantan completed in 2022 and 2023 have experienced a time overrun of 1 to 3 years and cost overrun 10% to > 20%. This study aims to analyze the risks of the project using a multi-method approach. Data were collected through the PLN UIP Kalbagtim 2022 Risk Assessment Report, literature reviews, interviews, and questionnaire surveys. The risk identification process identified 12 risk variables consisting of 63 risk criteria, risk analysis using the Severity Index (SI) method to determine the probability and impact values. The risk analysis results categorized the risks as follows: 2 extreme risk criteria, 30 high-risk criteria, 19 moderate-risk criteria, and 12 low-risk criteria. The Delphi method is used to determine alternative recommendations for risk responses for extreme and high-risk categories. The Analytical Network Process (ANP) method is used to identify priority risks and recommendations for risk responses to priority risk. The results of this study found three (3) priority risk variables: Land Acquisition risk with the highest weight of 0.20183, Right of Way (ROW) Clearence risk with a weight of 0.16829 and Permitting risk with a weight of 0.16564. Recomendations for priority risk responses to Land Acquisition risk includes forming a Task Force team to accelerate verification of land payment documents, involving community leaders, and provide transparent socialization regarding the appraisal process. For ROW Clearance risk, the recommendations include forming a Task Force to accelerate the verification of ROW documents, conducting consignment (depositing ROW compensation values in court), and collaborating with banks to facilitate the creation of mass accounts for ROW compensation payments. For Permitting risk, the recommendations include create a list of required permits and compile a submission timeline, holding audiences with relevant stakeholders to increase support for project activities, and conducting regular checkpoints to ensure document completeness before submitting permits.

Keywords: *Risk, Overhead Line and Cable Construction, Severity Index, Delphi, Analytical Network Process.*

A. INTRODUCTION

The development of a modern electrical system in the capital city of Nusantara (IKN) will drive investment, with PLN responsible for providing electricity based on clean and renewable energy. The electricity demand in IKN, around 900 MVA, will be met gradually, including the construction of generators, transmission, and distribution. The government focuses on new renewable energy sources, with the development of hydroelectric power plants in North and East Kalimantan, which will be distributed through SUTET and GITET, connecting all provinces in Kalimantan with a 500 kV network. The electricity supply plan for IKN for the period 2024-2030 is presented in Table 1 and Figure 1.

Table 1. Electricity Supply Plan for IKN

Deskripsi	2024	2025	2026	2027	2028	2029	2030
MVA	191	249	434	509	640	652	652
GWh	382	499	868	1,017	1,280	1,303	1.303

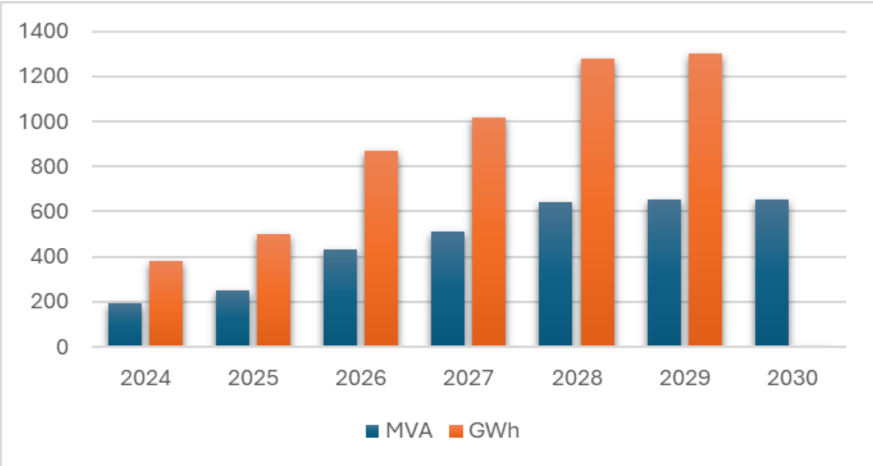


Figure 1. Electricity Supply Plan for IKN

Source: PLN RUPTL 2021-2030 (processed data)

Table 1 and Figure 1 shows a significant increase in the supply of electricity from 2024 to 2030, both in MVA and GWh, reflecting the rapid growth of energy demand in the National Capital City (IKN). This increase demonstrates PLN's efforts to enhance the reliability of the electricity system with energy efficiency, in line with its commitment to green growth and sustainability. The development of IKN, which adopts the concept of a "Green City," has been assigned to PLN by the Ministry of State-Owned Enterprises, based on the Minister of Energy and Mineral Resources Decree No. 36.K/HK.02/MEM.S/2023. PLN is implementing electricity infrastructure projects in IKN, including the 150 kV Kariangau Substation (GI), 150 kV transmission lines (SUTT), and 150 kV SKTT, as shown in Figure 2.

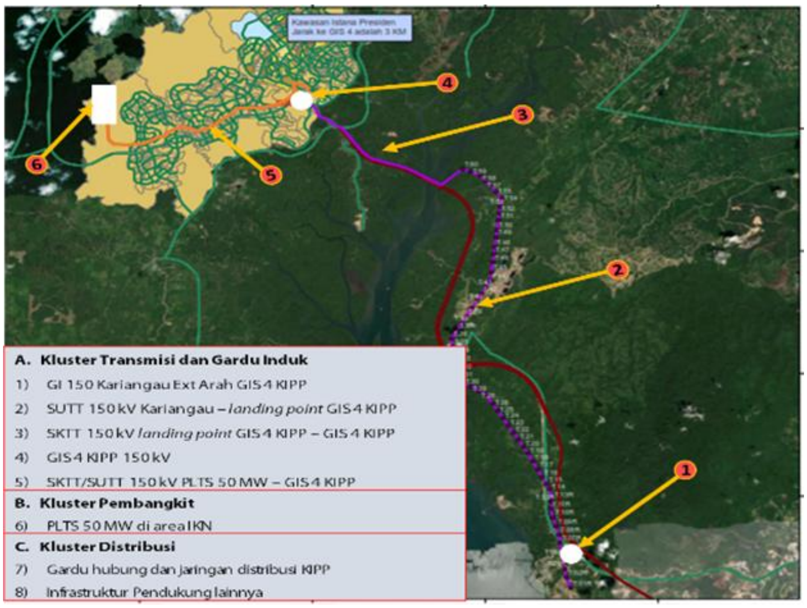


Figure 2. Planned 150 kV SUTT and SKTT Routes in the IKN Area

Source: PLN UIP East Kalimantan

The development of electrical infrastructure in the IKN area, as shown in Figure 2, includes the 150 kV SUTT transmission line from Kariangau to the Landing Point and the 150 kV SKTT from the Landing Point to GIS 4 IKN. This project supports the sustainability of IKN and connects to the South, Central, and East Kalimantan (Kalseltengtim) transmission network. The determination of the transmission route is based on the results of initial identification and planning surveys.

From the project, a risk analysis was conducted to identify potential factors that could hinder the completion of the project, with the goal of ensuring the project is completed on time and according to plan, as well as serving as a lesson learned for future infrastructure development. The process of constructing SUTT and SKTT involves various complex technical, logistical, and managerial aspects, each of which carries the potential for risks. These risks can arise from various sources, including environmental conditions, changes in project requirements, resource limitations, and technical or safety issues. This study is considered important because, based on the data obtained, 8 out of 10 PLN projects in Kalimantan that completed their construction in the period of 2022 and 2023 experienced time overruns of 1 to 3 years and cost overruns of 10% to more than 20%.

In-depth risk analysis is essential to better understand risks and design effective strategies to mitigate their impact, ensuring the success of the 150 kV GI Kariangau to GIS 4 IKN power line project. Data is collected through project documentation and surveys to validate the risk variables. The risk measurement involves the Severity Index (SI) and risk level measurement, considering both frequency and impact (Almira et al., 2021); (Maslina et al., 2022). Risk evaluation will involve designing preventive actions using the Delphi method to achieve consensus on risk causes and their probability and impact (Laine et al., 2024). Delphi facilitates anonymous expert discussions to minimize subjectivity (Abramov &

Alzaidi, 2023). If consensus is not reached in the first round, the process continues until agreement is achieved (Al-Rawe & Naimi, 2023).

Subsequently, prioritization of preventive actions will use the Analytical Network Process (ANP), developed by Saaty in the 1990s, which handles complex multi-criteria decision-making problems (Purba, 2023). ANP evaluates the interrelated factors, providing structured feedback and synthesis analysis (Riyadi et al., 2024). This risk analysis offers a comprehensive view of potential risks in the 150 kV GI Kariangau to GIS 4 IKN power line project and solutions to address them.

B. LITERATURE REVIEW

1. Project Management

A project is a temporary endeavor involving the integration of resources such as people, materials, equipment, and capital to achieve specific goals within defined constraints of quality, cost, and time—commonly referred to as the Triple Constraint (Harrison et al., 2024). Quality emphasizes meeting agreed specifications and ensuring fitness for purpose, even if it requires higher costs and extended timelines. Time pertains to delivering the project within the agreed schedule, where delays could compromise efficiency and increase expenses. Cost focuses on adhering to budgetary limits while balancing time and quality considerations. Project management, as defined by Husen (2010), entails applying knowledge, skills, tools, and techniques to achieve optimal outcomes in performance, quality, time, and safety. According to the PMBOK® Guide, project management processes encompass initiation, planning, execution, monitoring, and closure, complemented by ten knowledge areas, including scope, cost, quality, risk, and stakeholder management. These frameworks ensure efficient planning, execution, and integration of resources to meet project objectives effectively. Quality ensures the final product meets agreed-upon standards, time focuses on completing tasks within a set schedule, and cost emphasizes adhering to the budget. Balancing these aspects is crucial for successful project execution (Atkinson, 1999).

Project management applies knowledge, skills, tools, and techniques to project activities to meet project requirements (PMBOK, 2021) The process includes initiating (defining the project), planning (developing comprehensive strategies), executing (implementing plans), monitoring and controlling (tracking progress and making adjustments), and closing (finalizing all activities). Additionally, the ten knowledge areas of project management—such as scope, schedule, cost, quality, and risk management—ensure effective integration and stakeholder communication, contributing to the project's overall success (PMBOK, 2021).

2. Risk Management

Risk is defined as the likelihood of an event causing failure or potential loss Muhlbauer, (2004) in (Wantouw & Mandagi, 2014). It involves decision-making conditions where specific alternatives may lead to predetermined outcomes (Lima et al., 2021). In project contexts, risk refers to uncertain events with negative impacts on project goals, such as financial or physical consequences affecting timelines, quality, and costs (Ma et al., 2021). are inherent in projects, influencing performance, such as delays leading to increased costs (Pasaribu, 2021). Broadly, risks are categorized as speculative risks, which can result in loss or gain, and pure risks, which only pose potential losses (Mas'ud et al., 2023). In projects, pure risks often arise, including those related to management, technical implementation, contracts, and external factors like economic, social, and political conditions Soeharto, (2001), in (Wantouw & Mandagi, 2014).

According to Caltrans (2012) in (Pasaribu, 2021) there are several stages of project risk management, as follows:

a. Risk identification
b. Risk analysis
c. Risk evaluation
d. Risk respons
e. Risk monitoring

3. Previous Research Literature

This study aims to identify, analyze, and develop risk mitigation strategies for the project. It builds upon previous research that has explored risks in various construction and power infrastructure projects, utilizing different methodologies, particularly the Severity Index, PI Matrix, House of Risk (HOR), and Analytical Network Process (ANP). The previous research as a key literature supporting is shown in Table 2.

Table 2. Overview of the Key Literature Supporting

No	Title, Author	Topic/Research Focus	Methods	Key Finding
1.	"*Analisis Risiko Keterlambatan Proyek di Kabupaten Aceh Tengah*" (Fitra et al., 2023)	To identify risk factors influencing the time performance of construction projects in Central Aceh Regency.	Quantitative analysis using the Severity Index and the Probability and Impact Matrix.	Four dominant risk factors and 20 risk factors categorized as medium and high were identified. Two medium-category factors are related to design and construction, while two high-category factors are associated with financial issues. These four factors significantly impact project timelines, with potential delays or even project termination, leading to increased costs and losses for contractors.

No	Title, Author	Topic/Research Focus	Methods	Key Finding
2.	"*Analisis dan Respon Risiko Pada Proyek Konstruksi Gedung*" (Sopiyah & Salimah, 2020)	Identifying the risks that occur and their impact on building construction projects, as well as analyzing the response to those risks within the project	The Severity Index Method is used to assess risk responses, including time estimation errors, design changes, and schedule alterations.	The percentage of risk variables affecting the performance or execution of construction projects is as follows: time estimation errors at 67.8%, design changes at 23.9%, and schedule alterations at 8.3%.
3.	"Assessment of Risk Management for Small Residential Projects in Thailand" (Ayudhya & Kunishima, 2019)	Identifying the key factors contributing to project failures in housing developments	Severity Index Method	These factors include operational errors, payment delays, design flaws, fluctuations in operating costs, construction delays, interest rates, natural disasters, employment fluctuations, political instability, and changes in regulations.
4.	"Analysis of Factor's Causing Delay in Road Project by Severity Index Method" (Avhad & Waysal, 2020)"	Evaluating the project timeline achievements of road construction, identifying the causes of delays, and analyzing related factors from the contractor's perspective.	Severity Index Method	The key factors most influencing road construction failures include accidents during construction, rising material costs, cost variations, and time delays. These factors are analyzed using the Severity Index Method and mathematically processed with the assistance of Excel and Google Forms, with the results subsequently calculated.
5.	"*Analisis Risiko Konstruksi pada Pekerjaan*	Identifying the risks associated with the implementation	Severity Index Method	The dominant risk variable related to time is challenges concerning site conditions. Meanwhile, the most

No	Title, Author	Topic/Research Focus	Methods	Key Finding
	Pembangunan Sutet 500 kV Balaraja-Kembangan" (Nugroho et al., 2022)	of the 500 kV SUTET Balaraja - Kembangan construction project, analyzing the dominant risks, and understanding the responses to the most significant risks.		significant cost-related risk is poor contractor performance. These findings provide valuable insights for managing risks and ensuring the successful implementation of the SUTET Balaraja - Kembangan construction project as planned.
6.	*"Manajemen Risiko dan Analisis Keputusan Solusi Material Obsolete Mechanichal Menggunakan Metode HOR dan ANP (Studi Kasus: PT XYZ)"* (Soetjipto et al., 2021)	Identifying risks caused by the accumulation of obsolete mechanical materials and determining the best solutions to utilize these materials, followed by proposing alternative uses that can enhance the company's efficiency and profitability.	The House of Risk (HOR) and Analytical Network Process (ANP) methods were used to analyze the situation.	Six risk events and 16 risk agents were identified, with the highest priority risk being the decreasing and limited warehouse capacity, which had the highest Aggregate Risk Potential (ARP) value attributed to risk agent A10. The best alternative selected was modification, with the highest priority score of 0.105. The second alternative was donation to academics, with a score of 0.073, followed by wholesaling at 0.043, and scrapping at 0.040.
7.	*"Penentuan Alternatif Pilihan Strategi Mitigasi Risiko Kecelakaan Kerja dengan*	Identifying the main criteria and sub-criteria causing workplace accidents and determining the most effective	Analytical Network Process (ANP) Method	The main criteria causing workplace accidents, ranked by highest weights, are as follows: environment (25.4%), materials (20.7%), humans (13.8%), machinery (12.5%), and methods (5.8%). The most influential sub-criteria is

No	Title, Author	Topic/Research Focus	Methods	Key Finding
	Metode ANP di PT XYZ" (Fitri, et al., 2020)	mitigation strategies to reduce accident risks based on priority weights obtained from ANP analysis.		the production room temperature, with the highest weight of 12.9%.

C. METHODS

The research is a qualitative descriptive study, employs a literature review approach and surveys several respondents with expertise in transmission network construction projects. The research consists of four stages: preliminary study, research instrument preparation, data collection, and data analysis.

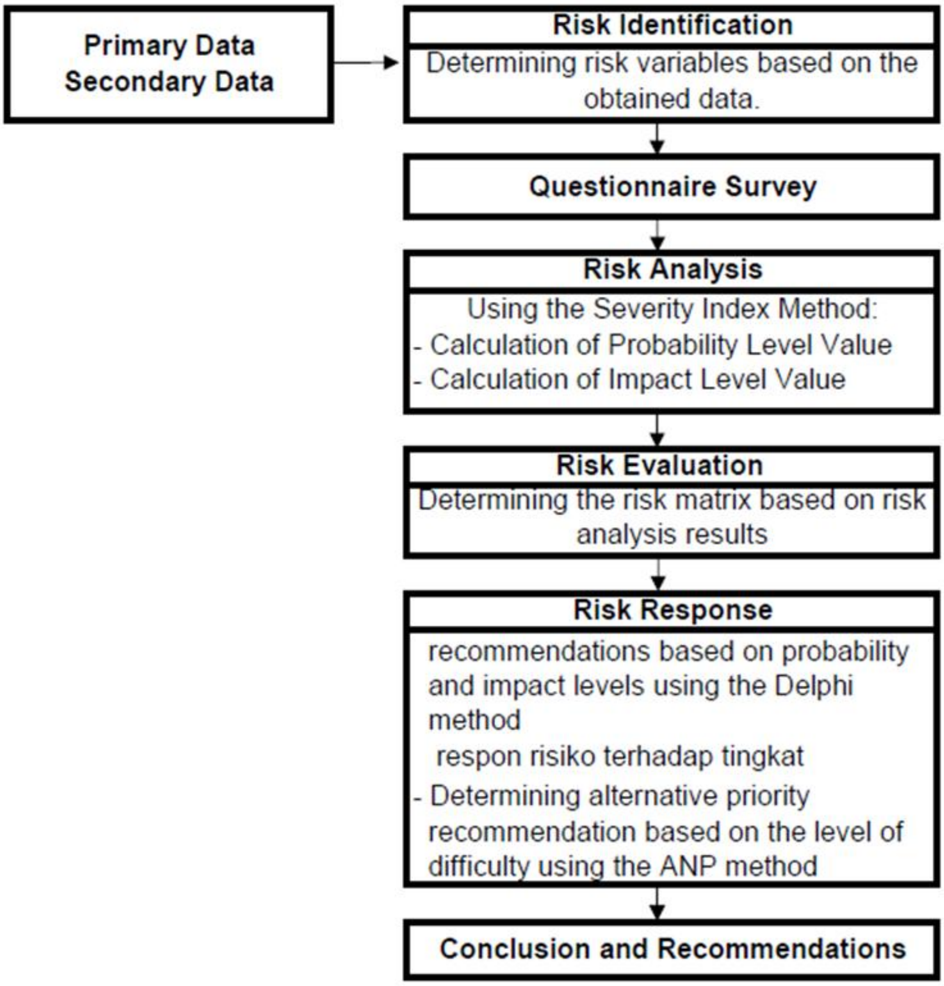


Figure 4. Research flow

The research flowchart in Figure 4 shown the linear process flow of risk analysis for the project. The risk management steps are crucial to ensuring the smooth execution and success of this project. The first stage is risk identification, where various potential risks that may impact the project must be carefully identified. Once the risk identification process is complete, the next step is risk analysis using the Severity Index Method. The results of this analysis are then evaluated by organizing them into a risk matrix, which helps prioritize risks based on their likelihood of occurrence and potential impact.

Following this, alternative risk responses are developed using the Delphi Method, integrated with the Analytical Network Process (ANP). This approach helps determine priority alternatives by capturing the complex interactions between various risk factors. Ultimately, this process supports strategic decision-making for effective risk management in the project.

The risk matrix analysis results were evaluated using the Delphi method to gather expert opinions on project risks. Delphi collects subjective expert views to reach a consensus. Subsequently, the Analytical Network Process (ANP) approach was applied to structure the analysis, ensure objectivity, and test consistency, prioritizing recommendations based on difficulty levels. The integration of the Severity Index, Delphi, and ANP methods is shown in Figure 5.

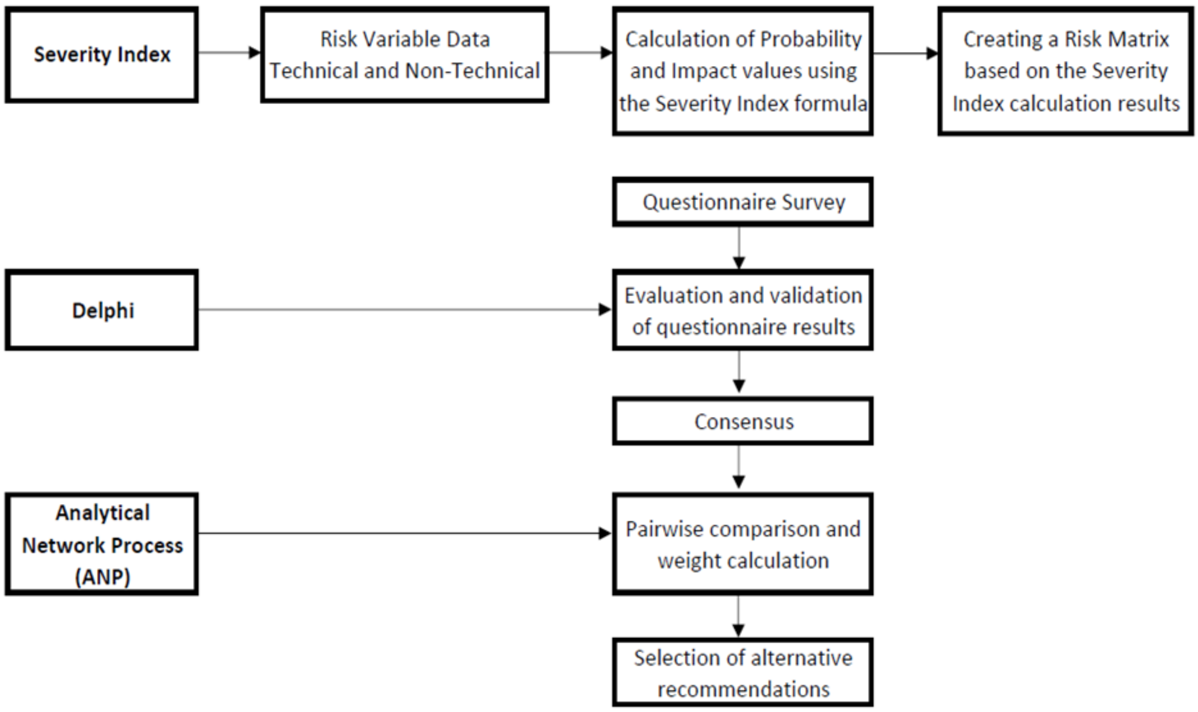


Figure 5. The integration relationship of Severity Index, Delphi and ANP

D. RESULT AND DISSCUSSION

This section presents the results and discussion of the research. The research findings outline the analysis and evaluation of risks, along with the calculation process using the Severity Index Method. Subsequently, alternative risk mitigation measures are developed using the Delphi Method, and finally, priority recommendations are determined using the Analytical Network Process (ANP) in alignment with the objectives of this study.

1. Risk Identification

The risk identification process in this study aims to gather all potential risks that may hinder the achievement of project completion goals for the construction of the project. The risks in this project were identified through a literature review of the and various previous studies related to risk management in construction projects. The project risks in this research are categorized into 12 risk variables is shown in Table 3.

Table 3. Risk Variables

No	Variable	Code
1	Delay in Permits	RA
2	Project Design	RB
3	Land Acquisition Delays	RC
4	Right of Way (ROW) Delays	RD
5	Procurement Process Delays	RE
6	Project Material	RF
7	Negative Progress Deviation	RG
8	Work Quality	RH
9	Commissioning & Energizing Delays	RI
10	Delayed Issuance of SLO (Operation Worthiness Certificate)	RJ
11	Delay in Project Handover	RK
12	Delays in the Procurement Process	RL

2. Risk Analysis

Qualitative analysis provides a general overview of risk levels using descriptive scales, such as low, medium, or high, which can then be clarified through semi-quantitative or quantitative analysis. The assessment of risk probability and impact combines respondents' estimates of identified risk variables, providing an overview of project risk potential and a basis for decision-making and mitigation strategies. Probability and impact values are obtained through questionnaires, and the results are input to the risk matrix to determine the mapping of each risk variable and criteria.

3. Risk Matrix

The process of developing a risk matrix begins with risk identification, where all potential risks that may occur in the project are gathered and analyzed. In this study, the risk matrix is developed based on AS/NZS 4360:2004, assessing probability and impact as outlined in Table 5. The impact and likelihood scores are combined to determine the severity of risks, which are then plotted into a risk matrix to create a risk map. The resulting plot identifies risks at extreme and high levels, which require special handling, as shown in Table 4.

Table 4. Risk Map

Risk Level		Concequences/Impact				
		Insignificant	*Minor*	*Moderate*	*Major*	*Extreme*
		1	2	3	4	5
Probability/Likelihood	A(*Almost Certain*)					
	B (*Likely*)			G4, G5	A5, C11, D4, D5, D9, F2, F4, G1, G2, K1, K3	C5, D5
	C (*Possible*)		A1, D1, D2, F8, F11, H2	A2, A3, A4, B3, C2, C3, C4, C6, C7, C10, D6, E3, E4, F1, F5, H3, K2	G3	
	D (*Unlikely*)		B1, C8, C9, D7, D8, F7, F9, H1, I2, J2, L2, L3	B2, C1, D3, E1, E2, F3, F6, F10, I1, I3, J1, J3, L1		
	E (*Rare*)					

Based on Table 4, several variables with high risk levels are identified, such as A2, A3, A4, B3, C2, C3, C4, C6, C7, C10, D6, E3, E4, F1, F5, G3, G4, G5, H3, and K2. Variables A5, C11, D4, D9, F2, F4, G1, G2, K1, and K3 are expected to have high probability and major impact, while C5 and D5 have very high probability with extreme impact. These risks require special attention in management and mitigation to minimize negative impacts and prevent any hindrance to the project execution and completion. Risks will be categorized into extreme, high, moderate, and low groups. Then, each risk event will be presented with its respective risk code along with its category, shown in Table 5.

Table 5. Risk Category Grouping

Risk Category	Risk Code
Extreme	C5, D5
High Risk	A2, A3, A4, A5, B3, C2, C3, C4, C6, C7, C10, C11, D4, D6, D9, E3, E4, F1, F2, F4, F5, G1, G2, G3, G4, G5, H3, K1, K2, K3
Moderate Risk	A1, B2, C1, D1, D2, D3, E1, E2, F3, F6, F8, F10, F11, H2, I1, I3, J1, J3, L1
Low Risk	B1, C8, C9, D7, D8, F7, F9, H1, I2, J2, L2, L3

4. **Risk Response**

Risk response or risk handling is part of risk management that focuses on formulating steps or strategies to address identified risks. These steps are tailored to the risk level—low, medium, high, or extreme—to ensure more precise and effective handling. Generally, there are four types of risk controls: risk avoidance/reduction, risk transfer, risk mitigation, and risk acceptance. For risks viewed as opportunities or positives, strategies include exploitation, sharing, and enhancement.

a. Determining Risk Response Recommendation Alternatives with Delphi Method

The next step involves analyzing using the Delphi method. The Delphi method is defined as a group process involving interaction between researchers and experts on a specific topic, typically via questionnaires (Yousuf, 2007). This method aims to achieve consensus on future projections through systematic information gathering. In risk management, the Delphi method can be applied at any stage when expert consensus is required. In this study, it is used in the risk response phase. Data is collected and processed based on questionnaires distributed to respondents.

The responses are analyzed and quantitatively evaluated using statistical methods to identify the level of consensus among experts. The primary goal of the Delphi method is to reach this consensus. To measure consensus, statistical analysis uses Standard Deviation and Interquartile Range (IR).

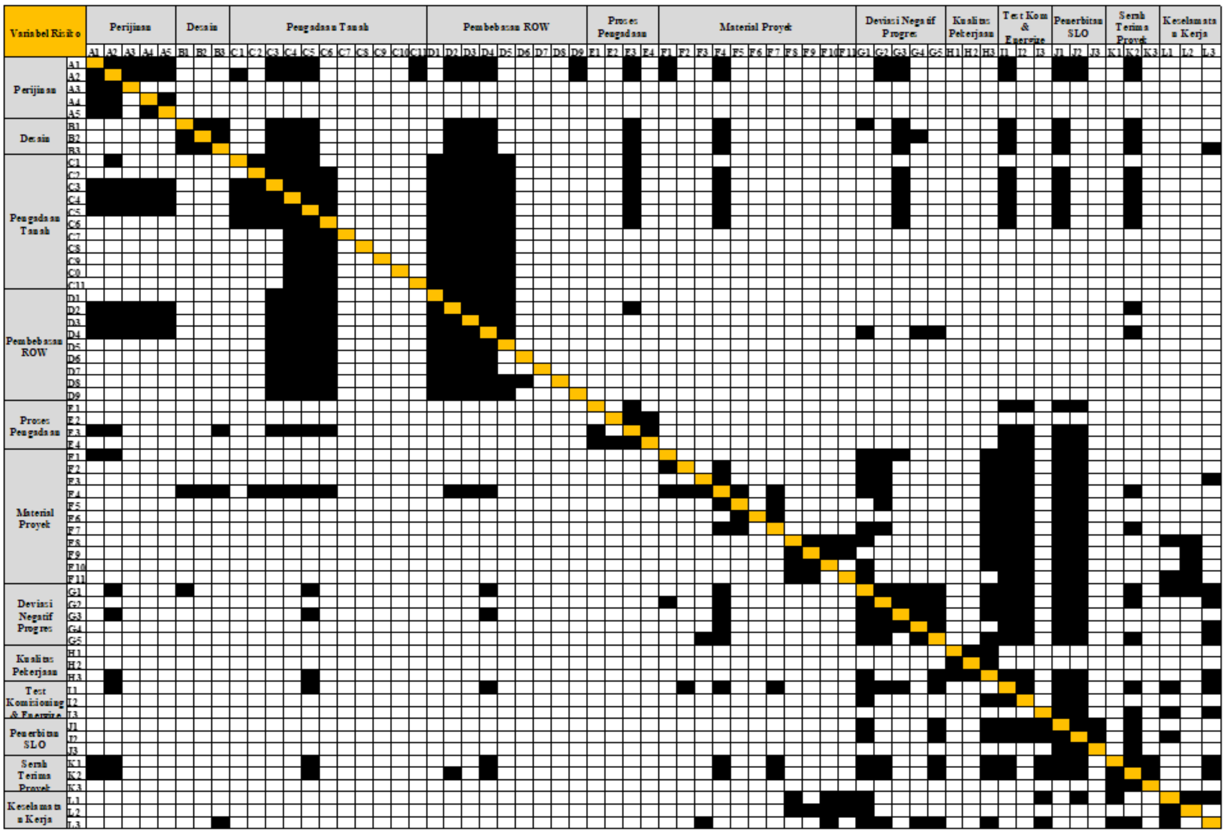
An instrument is considered to have achieved consensus if the standard deviation is <1.5 and the interquartile range is <2.5. If one or both criteria are not met, it indicates that the experts' opinions on the variable have not reached agreement. Consensus is determined through the opinions drawn from the questionnaire results from the respondents.

Based on the questionnaire result, the opinion gathering results have reached consensus, indicating that experts consider the risk variables important and highly potential for mitigation. Appropriate responses are needed to reduce the likelihood or impact of these risks, or both. Based on the risk matrix mapping in Table 4 and the risk grouping in Table 5, risks at the extreme and high-risk levels require special handling.

b. Determining Priority Recommendation Alternatives with ANP

The Analytic Network Process (ANP) method, developed by Saaty in 1996, allows for interaction and reciprocal relationships between variables within a risk group and across different risk groups, known as internal and external dependencies. This method evaluates the complexity of a problem using a priority scale to synthesize results and determine the main priorities. The goal of ANP is to analyze the influence of various factors by assuming solutions to the problem. It also aims to identify which risks have the highest impact among the interrelated risks and which causes have the greatest probability in the relationship between risk causes. ANP requires interrelated data to assign weights to each risk criterion. The ANP-based risk analysis method requires interconnected risk data. The development of the ANP model to determine the relationships between risks and for creating risk criteria relationship matrix is conducted through discussions with experts who have experience and are directly involved in the project. In this study, the interrelationships between risk variables are presented in Table 7 below:

Table 7. Risk Criteria Relationship Matrix



c. ANP Model for Risk Variables and Criteria

The process of developing the ANP linkage model using Superdecision 3.1 software involves determining clusters and nodes, followed by establishing the relationships between the clusters and nodes being used, and then depicting the linkage model in the form of a network. The modelling is shown in Figures 6 and 7.

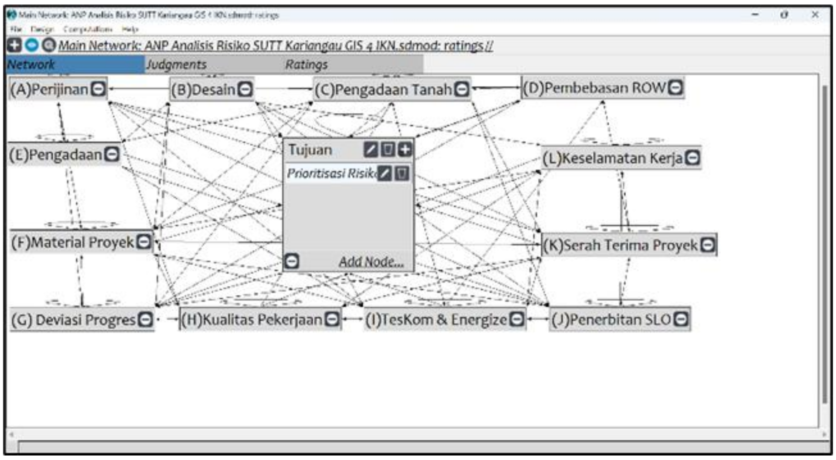


Figure 6. ANP Model of Relationships Between Risk Variables

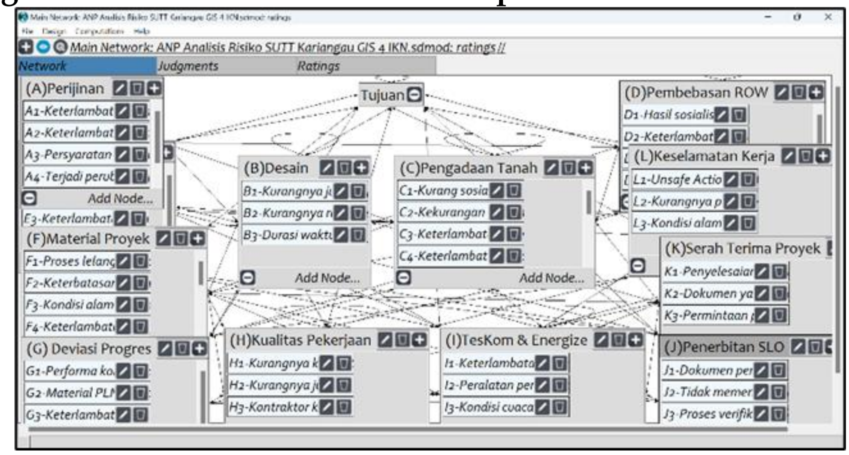


Figure 7 ANP Model of Relationships Between Risk Criteria

d. Analysis of Risk Priority Weights Based on ANP Model Output

Pairwise comparison data was input and processed in the ANP model using Superdecision 3.1 software. Through pairwise comparison, the software computed the weights for each risk, identifying those with the highest interrelation. This process automatically generated both unweighted and weighted supermatrix. From the weighted supermatrix, further processing resulted in the ANP model output in the form of a limit matrix. The processed data output, showing risk priority rankings based on the ANP model using Superdecision 3.1, is shown in Figure 8.

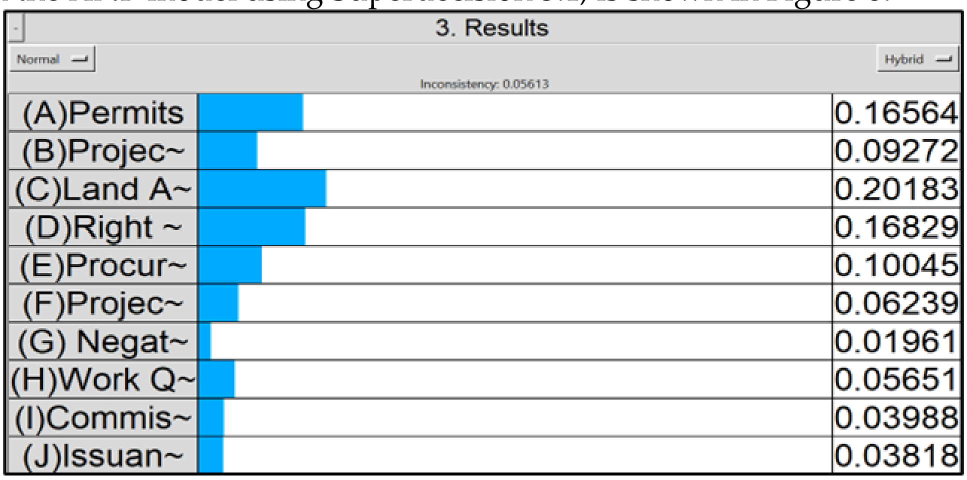


Figure 8. Risk Variable Priority Weights

Priority values are valid if the consistency ratio (CR) is below 0.1, as per Saaty and Vargaz (2006). Based on Figure 4.4, the CR obtained is 0.05613, which is acceptable and indicates consistency in respondents' answers. This ensures optimal solutions. The data analysis using Superdecision 3.1 revealed the priority rankings of 12 risk variables affecting the construction of the 150 kV transmission line and cable project from the Kariangau Substation to GIS 4 in the Nusantara capital. Figure 8 highlights that Land Acquisition Risk (RC) is the top-priority risk, with a weight of 0.20183, making it the most influential factor in the project. This is followed by ROW Clearance Risk (RD) (0.16829) and Permit Risk (RA) (0.16564).

E. CONCLUSIONS

The risk identification results obtained 12 risk variables with a total 63 risk criteria. Using the Severity Index method an analysis of these risk was conducted to determine the risk categories. Based on the risk analysis results, the risk categories were determined as follows: 2 extreme category risk criteria, 30 high-risk category risk criteria, 19 moderate category risk criteria, and 12 low-risk category risk criteria. The large number of high-risk variables indicates that the project faces significant challenges that could impact or hinder its completion. In this study, the Delphi method was utilized to determine alternative risk responses, based on recommendations from expert (respondents) who were directly involved in the project implementation. The risk responses were designed to lower the risk level, particularly for risks at the extreme and high risk. Based on the Analytical Network Process (ANP) risk analysis results, three (3) most priority risk variables were identified: Land Acquisition with the highest weight of 0.20183, Right of Way (ROW) Clearence with a weight of 0.16829 and Permits with a weight of 0.16564. Recommendations for priority risk responses to Land Acquisition risk include forming a Task Force team to accelerate the verification of land payment documents, involving community leaders, and providing transparent socialization about the appraisal process. Recommended responses for ROW Clearence risk include forming a Task Force team to accelerate the verification of ROW documents, initiating consignment (depositing ROW compensation values in court), and collaborating with the Banks regarding the creation of mass accounts for ROW compensation payments. Lastly, recommended responses for Permitting risk include compiling a list of required permits and creating a submission timeline, holding audiences with relevant stakeholders to increase support for project activities, and conducting regular checkpoints to ensure document completeness before submitting permits.

REFERENCES

1. Abramov, I. L., & Alzaidi, Z. A. (2023). Assessing of sustainable construction quality in Iraq under conditions of risk factors. *IOP Conference Series: Earth and Environmental Science, 1232*(1). https://doi.org/10.1088/1755-1315/1232/1/012041.
2. Al-Rawe, Y. H. A., & Naimi, S. (2023). Project Construction Risk Estimation in Iraq Based on Delphi, RII, Spearman’s Rank Correlation Coefficient (DRS) Using

Machine Learning. *International Journal of Intelligent Systems and Applications in Engineering, 11*(5s), 335–342.
3. Almira, A., Anjastari, H. A., Gaol, D. K. L., Zuna, H. T., & Wahyudi, A. R. (2021). Risk Analysis in Developing Horizontal to Vertical Housing Using Severity Index Method (Case Study: Rumah Susun Paldam, Bandung). *Plano Madani, 10*(1), 99–108.
4. Avhad, S. A., & Waysal, S. M. (2020). Analysis of Factor's Causing Delays in Road Project by Severity Index Method. *International Journal of Engineering and Advanced Technology, 10*(1), 308–312. https://doi.org/10.35940/ijeat.a1808.1010120
5. Ayudhya, B. I. N., & Kunishima, M. (2019). Assessment of Risk Management for Small Residential Projects in Thailand. *Procedia Computer Science, 164*(1), 407–413. https://doi.org/10.1016/j.procs.2019.12.200
6. Durdyev, S., & Hosseini, M. R. (2020). Causes of delays on construction projects: a comprehensive list. *International Journal of Managing Projects in Business, 13*(1), 20–46. https://doi.org/10.1108/IJMPB-09-2018-0178
7. Fitra, W. K., Rauzana, A., & Mahmuddin, M. (2023). Analisis Risiko Keterlambatan Proyek di Kabupaten Aceh Tengah. *Journal of The Civil Engineering Student, 5*(1), 99–105. https://doi.org/10.24815/journalces.v5i1.24619
8. Harrison, J., Lewis, M., Roehrich, J., & Davies, A. (2024). Scale in Project Management: A Review and Research Agenda. *Project Management Journal, 55*. https://doi.org/10.1177/87569728241256611
9. Laine, V., Valdez-Banda, O., & Goerlandt, F. (2024). Risk maturity model for the maritime authorities: a Delphi study to design the R-Mare matrix model. *WMU Journal of Maritime Affairs*, 0123456789. https://doi.org/10.1007/s13437-023-00328-z
10. Lima, F. de A., Marcelino-Sadaba, P., & Verbano, C. S. (2021). Successful implementation of project risk management in small and medium enterprises: a cross-case analysis. *International Journal of Managing Projects in Business, 14*(4), 1023–1045. https://doi.org/10.1108/IJMPB-06-2020-0203
11. Ma, M., Al Matin, R., Azhar Firdausi, A., Aski Safarizki, H., Bangun Nusantara Sukoharjo, V., & Letjend Humardani No, J. S. (2021). Risk Management Analysis of Construction Projects on Time Performance. *International Journal of Sustainable Building, Infrastructure, and Environment, 1*(1), 1–4.
12. Mas'ud, F., Mursidi, B., Darmawan, L. O. R., & Rustan, F. R. (2023). Analisis Manajemen Risiko Waktu dan Biaya Pada Proyek Konstruksi Pembangunan Rsud Tipe D Kota Kendari. *STABILITA: Jurnal Ilmiah Teknik Sipil, 11*(3), 122. https://doi.org/10.55679/jts.v11i3.43080
13. Maslina, Kurnia, M., Agustiyana, N., & Sari, H. M. (2022). Analisis Risiko Proyek Menggunakan Metode Severity Index Pada Proyek Pembangunan Kantor Lingkungan Samarinda. *Jurnal TRANSUKMA, 05*(01), 18–26.
14. Mustamin, M. R., Suleman, A. R., Djufri, H., Asrun, B., Mawarni, A. A. I., Fachriza, M., Putri, H., & Tuwo, M. (2023). Risiko Keterlambatan Waktu pada Pelaksanaan Proyek Pembangunan Bendungan Pamukkulu dengan Metode Matriks Risiko dan Metode AHP. *Jurnal Konstruksia, 15*(1), 145–158.

15. Nugroho, B., Romadhon, E. S., & Isfahani, M. N. (2022). Analisis Risiko Konstruksi Pada Pekerjaan Pembangunan Sutet 500Kv Balaraja-Kembangan. *Jurnal Teknik Sipil-Arsitektur,* 21(1), 44–53.
16. Pasaribu, R. (2021). *Penerapan Manajemen Risiko Proyek XYZ Menggunakan Pendekatan Failure Mode Effect Analysis dan Hybrid Fuzzy Multi Criteria Decision Making*. Fakultas Desain Kreatif dan Bisnis Digital.
17. PMBOK. (2021). *A Guide to the project management body of knowledge In Project Management Institute*.
18. Pradiani, A. D., & Nurhasanah, N. (2021). Kalbagtim dengan Metode Analytical Hierarchy Process dan Fault Tree Analysis. *Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi, 6*(1), 34–42.
19. Purba, I. (2023). Analisis Faktor-Faktor Penyebab Keterlambatan Proyek Penggantian Jembatan Sei Bamban Dengan Analytic Network Process (ANP). *Jurnal Ilmiah Indonesia, 3*(April), 386–393.
20. Riyadi, F. A., Permadi, D., & Mulyati, E. (2024). Evaluasi Pemilihan Vendor Cable Gland di Project Electrical Menggunakan Metode Analytic Network Process (ANP) pada PT Catur Elang Perkasa. *Jurnal Pendidikan Tambusai, 8*(1), 6376–6402.
21. Soetjipto, J. W., Qudsy, N. H., & Arifin, S. (2021). Analisis Risiko Keterlambatan Proyek Menggunakan Metode House of Risk. *Journal of Applied Civil Engineering and Infrastructure Technology, 2*(1), 19–26. https://doi.org/10.52158/jaceit.v2i1.149
22. Sopiyah, Y., & Salimah, A. (2020). Analisis Dan Respon Risiko Pada Proyek Konstruksi Gedung. *Construction and Material Journal, 2*(1), 46–58. https://doi.org/10.32722/cmj.v2i1.2757
23. Tawfek, A. M., & Bera, D. K. (2022). Delay in Construction Projects: Types, Causes and Effects. *Project Management Practices, 1*(November), 184–192.
24. Wantouw, F., & Mandagi, R. J. M. (2014). Risk Management of 150 KV Lopana-Teling High Voltage Development Projects. *Jurnal Ilmiah Media Engineering, 4(*4), 239–256.