p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 6, No. 3 March 2025 http://jist.publikasiindonesia.id/

Risk Analysis of The Implementation of Electricity Infrastructure Construction Case Study: Gistet 500 Kv Payton

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Keywords: delphi technique; expected monetary value; decision tree analysis.

ABSTRACT

This research analyzes the construction risks of the 500 kV Paiton High Voltage Substation (GISTET) and develops the most optimal risk treatment based on the risk management standard SNI 8615:2018. The research variables were derived from a literature review, followed by the Delphi Technique questionnaire to identify relevant risks from respondents. Subsequently, a qualitative analysis was conducted using the Consequence/Probability Matrix to identify the dominant risks, followed by a quantitative analysis using the Expected Monetary Value (EMV) calculation. The determination of the most optimal risk treatment for each dominant risk was obtained through Decision Tree Analysis (DTA). The research results identify 38 relevant risks, with 10 classified as dominant, categorized as high, very high, and extreme risks. The three risks with the highest EMV impact values are project execution time not aligning with the project schedule, suboptimal contractor performance, and delays in the arrival and mobilization of materials to be installed. The study's implications underscore the importance of proactive risk management in large-scale construction projects, aiming to minimize potential losses and ensure project success.

Introduction

PT. PLN (Persero) is a State-Owned Enterprise assigned by the government to plan and implement electricity infrastructure projects to meet the electricity needs of people throughout Indonesia (Antari, Gede, & Lasmini, 2022; Kurniawati, 2022). The construction of energy infrastructure is expected to anticipate the increasing demand for electricity while enhancing the reliability of the electricity system in each region, including Bali Province, which has become an international tourist destination (Silalahi & Sudarwati, 2018). As one of the world's top tourist destinations, the tourism sector in Bali Province contributes the largest share to the Province's Gross Regional Domestic Product, particularly from the accommodation sector, each year. The peak load of the electricity system in Bali Province is recorded in the Electricity Supply Business Plan (RUPTL) document of PT. PLN (Persero) from 2021 to 2030 is 980 MW. This load is supplied through the Java-Bali submarine cable system, which has a capacity of 400 MW (Alijoyo, Wijaya, & Jacob, 2022). The rest is sourced from several power plants spread across Bali Province. Taking into account historical business data, which shows an average growth rate of electric energy sales over the last 10 years of around 6.51%, and considering the trends of economic growth, population growth, and increased electrification, it is projected that the peak load in Bali Province until 2030 will be 1,515 MW. Thus, additional electricity infrastructure, including generators, transmission lines, and substations, is needed to serve the needs of the customers in question (Wantouw & Mandagi, 2014; Witari, 2017).

One plan to develop electricity infrastructure to anticipate load growth on the island of Bali is the construction of the 500 kV Paiton GISTET, which is part of a mega project called *Java Bali Connection* (JBC). This JBC will distribute low-cost energy from large-scale power plants in the Java System through the 500 kV Substation and Transmission from Paiton to Antosari.

This aligns with the Bali government's clean and green vision, which limits the construction of fossil fuel plants and prioritizes new and renewable energy. The 500 kV Paiton GISTET project is adjacent to the existing 500 kV GITET, which is located in the Paiton PLTU generation area, Paiton District, Probolinggo Regency, East Java. Given the 540-day implementation of the work and considering the social, technical, and complex problems in the field, it is necessary to conduct an appropriate GISTET 500 kV Paiton construction risk analysis to complete the project on time and meet the planned target. The risk analysis can provide benefits for PLN management in identifying which risks may affect the three key elements of a project: cost, quality, and time, allowing them to be anticipated or mitigated.

According to Situmorang, Arsjad, & Tjakra, (2018) In every construction project, risks can arise in every activity or work on the project, incredibly technical risks that can interfere with the project's implementation.

This study makes a new contribution by applying Decision Tree Analysis (DTA) to evaluate alternative risk treatment to the identified dominant risks. By comparing the EMV values of different treatment strategies, this study aims to identify the most cost-effective and efficient approach to reducing project risk. Furthermore, applying this method to large-scale infrastructure projects in Indonesia yields valuable findings that can benefit future energy infrastructure projects in the region.

The urgency of this research is further emphasized by the increasing importance of infrastructure development in Indonesia's economic growth. The construction of the 500 kV Paiton GISTET is crucial for meeting the growing electricity demand, especially in Bali, which plays a significant role in the country's tourism industry. By ensuring that risks are appropriately managed, this research aims to help PT. PLN (Persero) and other stakeholders make the right decisions to complete the project on time and within budget.

The purpose of this study is to provide a comprehensive risk analysis for the implementation of the 500 kV Paiton GISTET, focusing on identifying the most significant risks and suggesting appropriate mitigation strategies. This research will provide practical recommendations for risk management that can be applied to future infrastructure projects.

It is hoped that, with the risk assessment prepared, PT. PLN (Persero) can prepare risk mitigation measures to prevent potential risks from developing into actual ones that cause losses to all related parties. Considering the background description above, the author needs to conduct a research study titled "Risk Analysis for the Implementation of Electricity Infrastructure Construction: A Case Study of GISTET 500 kV Payton." (Hartono, 2023; Mustakim, 2025; Patrickson & Oei, 2024; Trisanto & Wiguna, 2012).

Research Methods

This study uses qualitative techniques. The researcher attempts to recruit respondents who have experience supervising the construction of electricity infrastructure. This research was conducted on the construction project of the 500 kV Paiton High Voltage Line Substation (GISTET), located adjacent to the existing 500 kV Paiton GITET in the Paiton PLTU generation area, Paiton District, Probolinggo Regency, East Java.

The primary and secondary data were used to identify risks in implementing electricity infrastructure construction. Primary data is obtained directly from the source or the first source, either through individual or group opinions of the subject, using interviews, forum group discussions (FGD), questionnaires, and observation results recorded directly from field conditions. In contrast, secondary data refers to literature, studies, and observational results from other individuals or related agencies that can support the research variables. The primary data used in this study included risk identification data based on the results of the Delphi Technique questionnaire (Hasan et al., 2022), as well as probability and impact data sourced from interviews with employees of PT. PLN (Persero) UIP JBTB has experience in constructing electricity infrastructure. The secondary data was obtained through literature studies, books, journals, and research that discussed electricity infrastructure projects, project management, and risk management.

Data Collection Methods

The methods used in obtaining the data needed in this study include the following:

1. **Document Review**

This method involves conducting a literature review of previous research on the risks associated with the construction of electricity infrastructure.

2. **Kuesioner Delphi Technique**

To define the risks in the GISTET 500 kV Paiton construction project, a Delphi questionnaire was used involving PLN UIP JBTB employees with experience in the field of electricity infrastructure construction. The opinions and suggestions given are then expressed as questionnaire answers. This method is a research approach used to obtain a consensus with a high degree of consistency (reliability) from a group of experts through a series of questionnaires interspersed with controlled feedback, allowing experts to review their answers and ensuring anonymity among respondents. This questionnaire was carried out in several stages. The initial stage aimed to gather information on respondents' experiences with facing risks during the construction of the 500 kV High Voltage Substation project. The second stage is preparing priorities and reviewing risk identification according to the previous stage to ensure that the confidence level in the data collected based on statistical analysis has been met, and so on (Ibrahim et al., 2023)

3. Interview

Interviews were conducted with PLN UIP JBTB employees involved in project planning or implementation. The criteria for interviewing employees include those who understand the background of the infrastructure project, have experience in the relevant field, and are aware of the project's risks. The interview was conducted to gather alternative risk treatment information and to deepen the understanding needed to support the answers provided by the respondents. Risk treatment for risks categorized as high, very high, and extreme will be determined based on the results of the interview.

The population under study comprises all PT employees. PLN (Persero) UIP JBTB who work in the office and the field. The research sample was determined using *the purposive sampling* technique. Hasan et al. (2022) explained that purposive sampling involves selecting a sample based on the research context, emphasizing the quality of information, credibility, and the wealth of information possessed by the respondents, rather than the number or representativeness. The researcher employs this technique by identifying unique characteristics that align with the research objectives. The criteria include knowledge, experience, and position in handling the 500 kV High Voltage Substation (GITET) construction project. Based on the specified criteria, the researcher identified five respondents, as listed in Table 1.

Risk Identification

Risk identification was obtained through a Delphi questionnaire, which was completed by research respondents individually. The risk variables used as the basis in the risk identification questionnaire are compiled based on literature studies from books, journals, and previous research on the implementation of electricity infrastructure construction.

Risk Analysis and Evaluation

Based on the results of risk identification, risk variables were further analyzed using qualitative methods. This involved plotting the probability level against the level of impact on the consequence/probability matrix, as determined by the results of the probability level and impact questionnaire administered to the respondents. PLN (2021) has provided a reference for the level of possible risk and the scale of impact associated with the electricity infrastructure construction business process, which can be used in risk research. Furthermore, the list of risks categorized as high, very high, and extreme will be reviewed quantitatively using an EMV assessment based on the questionnaire results from research respondents. The EMV value is obtained by multiplying the probability level by the impact cost, which is calculated using the Damage and Loss Assessment (DaLA) tool. This method is one of the most accurate methods to obtain data related to damage and losses caused by a risk event using assessments from questionnaires. The calculation of the impact value can be assessed based on several components, including direct damage, indirect loss, access disruption, functional impairment, and increased risk.

Risk Treatment

Implementing risk management helps organizations make informed decisions. One key decision is selecting the proper risk treatment for high-risk events, categorized as high, very high, and extreme risk. (Anita et al., 2023)One method that can be used in this case is decision tree analysis (DTA), which visualizes several alternative risk treatments to help users choose the best treatment from the available alternatives. (Musdar & Angriani, 2017). This study implements DTA by comparing the EMV of risk treatment of one alternative branch of risk treatment with another. This risk treatment EMV includes calculating the cost of risk treatment, the chances of success and failure of the implementation, and the probability and impact of the risk treatment after it is implemented. This method obtains an alternative EMV risk treatment with the most optimal value. Risk treatment selection process with a Decision (Alijoyo, 2021). Tree Analysis (DTA) and Expected Monetary Value (EMV) calculation diagrams (Darmawan, 2018)

Results and Discussion

The researcher's initial stage in this research activity is to determine the research variables based on literature studies obtained from books, journals, and other publications. Furthermore, based on the research variables, a Delphi questionnaire was developed to identify the relevant risk variables, which was then followed by an analysis of the level of likelihood and the scale of impact.

Risk Identification Results

Based on the initial stage of the risk identification process, carried out through literature studies, 39 risk variables were identified. The results of the risk identification then became a reference for the risk proposal in the first round *of the Delphi* questionnaire. Chou et al. (2007) stated that the consensus process in the Delphi method occurs when it has a percentage of 70% agreement of all respondents with 7 points on the assessment scale where the average value of each questionnaire point item is three or more with 4 Likert scales and has a median value of at least 3.25 or more. In the first round of the Delphi questionnaire, three risks were deemed irrelevant because they had an average score of less than 3 and a median value of less than 3.25. On the other hand, the respondents identified additional risks, which became inputs for the second round of the Delphi questionnaire (Apriani, Priadythama, & Herdiman, 2019). After running two rounds, 38 relevant risks were identified from the respondents, as these risks met the criteria of average and median values, indicating that the risk identification process in the second round had achieved consensus. The relevant risk variables identified through the Delphi questionnaire are presented in Table 2.

Risk Analysis Results

The next stage is to conduct a Qualitative Analysis by determining the level of likelihood and scale of risk impact using a questionnaire based on relevant risk variables. Based on the results of the frequency index analysis, 21 risks were identified in the "Small" probability level category, 10 risks in the "Medium" category, 6 risks in the "Large" category, and one risk in the "Very Large" category. (Afif, 2023). Meanwhile, from the results of the impact scale analysis/*severity index*, 10 risks with the "Minor" impact scale category, 18 risks with the "Medium" impact scale category, eight risks with the "Significant" impact scale category, and two risks with the "Very Significant" impact scale category. The results of the risk level evaluation are presented in Table 3. Furthermore, based on comparing the probability level with the impact level, it can be plotted into the risk matrix of constructing the 500 kV Paiton GISTET, as shown in Figure 3. Based on the figure, it can be concluded that there is one risk with the "Low" risk level category, 27 risks with the "Moderate" risk level category, three risks with the "High" risk level category, six risks with the "Very High" risk level category, and one risk with the "Extreme" risk level category. Considering the company's risk appetite, where categories of high, very high, and extreme risk levels must be addressed so that the risk level is at least moderate, it can be concluded that 10 risks require risk treatment.

Furthermore, a Quantitative Analysis was conducted by conducting interviews with respondents to obtain the EMV value, which results from the multiplication between the level of likelihood and impact. Where the impact cost assessment is obtained using the Damage and Loss Assessment (DaLa) tools. Damage and Loss Assessment calculation includes damage calculated as a substitute for physical value, whether entirely or partially damaged, and economic losses arising from temporarily damaged assets. Some components that can be considered in measuring risk assessments based on DaLA include damage (direct impact), loss (indirect impact), access disruption, functional impairment, and increased risk.

Risk Treatment

To achieve the most optimal risk treatment, it is necessary to conduct a decision-making process using a Decision Tree Analysis (DTA) diagram and compare Expected Monetary Value (EMV) values. The Decision Tree Analysis method is implemented by calculating the Expected Monetary Value (EMV) for each treatment option from each decision tree branch. This calculation involves determining the cost of risk treatment, the probability and financial impact of risk after treatment, and the chance of success. The alternative risk treatment with the least EMV value is optimal. Furthermore, the determination of alternative risk treatment is categorized into 4 (four) branches of decision, namely Risk *Avoidance*, Risk *Transfer*, Risk *Mitigation* (reducing the probability and/or impact of risk), and Risk *Acceptance* (accepting the risk) (Jannah, 2022; Radiansyah et al., 2023). Based on each risk in Table 4, interviews were conducted with respondents to gather information on alternative risk treatments, risk treatment costs, the probability of success of risk treatment, and the probability and financial impact of risk treatment. For example, for the risk of "The project implementation time is not by the project schedule," some of the risk treatments that can be carried out are BIM (Building Implementation Modelling) Implementation so that it can help manage resources efficiently and monitor progress in real-time, Buying CAR (Construction All Risk) and DSU (Delay in Start-Up) / ALOP (Advance Lost of Profit) insurance. Insurance and management meetings are held regularly at the head office and on-site to identify problems and obstacles (R.

Based on the results of interviews with respondents, a Decision Tree Analysis (DTA) diagram was obtained, as shown in Figure 4. Furthermore, it can be concluded that based on the results of the Decision Tree Analysis in Figure 4, the alternative risk treatment "BIM (Building Information Modelling) Implementation so that it can help manage resources efficiently and monitor progress in real-time" is the most optimal risk treatment alternative because it has the lowest EMV value compared to the other two risk treatment alternatives. The same method is used to obtain alternative risk treatment for dominant risks categorized as high, very high, and extreme. The results of the Decision Tree Analysis chart analysis for these dominant risks are presented in Table 5. After obtaining the most optimal risk treatment, followed by risk effectiveness and residual risk measurement, the risk management process is included in the *Risk Register*.

Research Gaps:

1. Limited Exploration of Social Impacts: The study primarily focuses on technical and financial aspects of risk management in constructing the 500 kV Paiton GISTET. A gap exists in exploring the social impacts of these risks, such as community disruption, stakeholder engagement, and public perception of electricity infrastructure projects.
2. Comparative Analysis: While the study uses a case study approach, a comparative analysis between different electricity infrastructure projects (e.g., in other regions or countries) could help generalize the findings or reveal region-specific patterns in risk management.
3. Long-Term Risk Assessment: The study assesses risks during the construction phase but does not fully consider the long-term operational and maintenance risks associated with the infrastructure after it is built. Future studies could focus on this aspect to provide a more comprehensive view of risk throughout the entire lifecycle of electricity infrastructure projects.
4. Technological Integration: The study highlights the use of BIM for time management. However, there is a gap in understanding the role of emerging technologies such as

AI and machine learning in predicting and mitigating risks in large-scale infrastructure projects.

Implications:

1. Policy and Decision Making: This research's findings can inform PT's policy decisions. PLN (Persero) and other stakeholders in the electricity sector. By understanding dominant risks and optimal risk treatments, decision-makers can allocate resources more effectively to mitigate high-impact risks and ensure timely project completion.
2. Future Research Directions: The research opens avenues for exploring the social and environmental dimensions of electricity infrastructure projects, which are increasingly important in sustainability and public acceptance. Future research could integrate these factors into a broader risk management framework.
3. Improvement of Risk Management Frameworks: This study can help improve existing risk management frameworks in Indonesia's electricity sector by providing a more data-driven and structured approach to risk identification and treatment. The application of Decision Tree Analysis (DTA) and Expected Monetary Value (EMV) calculations could be standardized in future projects with similar objectives.

Conclusion

GISTET 500 kV Paiton is one of the most vital electricity infrastructures because it plays a crucial role in distributing affordable energy from large-scale power plants in Java to Bali. Identifying risks in the GISTET 500 kV Paiton construction project is carried out through a literature review based on books, journals, and other publications, followed by the application of the Delphi technique method. Based on this method, 38 relevant risks were obtained that the respondents had agreed upon. The risk analysis and evaluation process is carried out using a qualitative method, namely *the Consequence/Probability Matrix*, followed by calculating the cost of DaLA (*Damage and Loss Assessment*). Based on this method, one risk falls into the Low category, 27 risks are classified as Moderate, three are classified as High, six are classified as Very High, and one is classified as Extreme. Considering the company's risk appetite, 10 Risks that require risk treatment will be obtained. Alternative risk treatment, considered the most optimal for high, very high, and extreme category risks, was obtained using the *Decision Tree Analysis* (DTA) diagram method and comparing Expected Monetary Value (EMV) values based on expert interviews. The three risks with the highest EMV impact value and the most optimal risk treatment are as follows: (1) The project implementation time is not by the project schedule, with the risk treatment of BIM (*Building Information Modelling) Implementation risk*; (2) The performance of the contractor is not optimal, with the risk treatment of the addition of a supervision consultant who has expertise in the field of *project management*; and (3) The delay in the arrival/mobilization of materials to be installed with the risk treatment of periodic consignment meetings related to the acceleration of *material approval* and monitoring of material arrivals.

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