Journal of Business, Social and Technology
Volume 6, Issue 2, 58-65
e_ISSN: 2807-6362
https://bustechno.polteksci.ac.id/index.php/jbt/index
DOI: doi.org/10.59261/jbt.v6i2.518

Design of Project Risk Management to Mitigate Project Delay in the Onshore Construction Industry

***Firdaus Yusri Muhammad**
Institut Teknologi Bandung, Indonesia

Gatot Yudoko
Institut Teknologi Bandung, Indonesia

Muhammad Hanafi
Institut Teknologi Bandung, Indonesia

***Corresponding author:**
Firdaus Yusri Muhammad, Institut Teknologi Bandung, Indonesia.
✉ firdaus_muhammad@sbm-itb@ac.id

Article Info :
Article history:
Received: July 12, 2025
Revised: September 15, 2025
Accepted: November 22, 2025

Keywords:
project delay; project risk management;
failure mode and effect analysis (FMEA);
project management body of knowledge (PMBOK);
onshore construction;

Abstract

Background: Project delays remain a critical issue in the land-based construction industry, often leading to financial losses and missed business opportunities, particularly under lump-sum contract schemes. The coastal protection project undertaken by PT Sabar Sejahtera experienced a three-month delay, indicating weaknesses in risk management practices during the early stages of the project.
Aims: This study aims to design a structured project risk management system to mitigate schedule delays in land-based construction projects through a case study of the PT Sabar Sejahtera coastal protection project.
Methods: A mixed-method approach combining qualitative and quantitative techniques was employed. Primary data were collected through focus group discussions (FGDs) with key project stakeholders, while secondary data were obtained from internal company documents. Root cause analysis was conducted using a Current Reality Tree (CRT) to identify the main causes of project delays, and proposed solutions were developed using a Future Reality Tree (FRT). Risk evaluation was performed using Failure Mode and Effects Analysis (FMEA) to calculate the Risk Priority Number (RPN), supported by the application of a project risk management framework based on the PMBOK 6th Edition.
Result: The findings indicate that the primary causes of project delays were systematic errors during the tendering and planning stages, as well as the absence of a formal risk mitigation plan. These factors generated a domino effect that adversely affected procurement processes, equipment availability, project scheduling, and the main contractor's confidence.
Conclusion: The study concludes that implementing an integrated and comprehensive risk management system from the early stages of a project is essential to prevent similar delays in the future. Enhancing tendering and planning processes through early cross-departmental involvement and applying the full PMBOK risk management cycle can significantly improve project efficiency and control in complex construction environments.

To cite this article: Muhammad, F. Y., Yudoko, G., & Hanafi, M. (2025). Design of Project Risk Management to Mitigate Project Delay in the Onshore Construction Industry. *Journal of Business, Social and Technology*, 6 (2), 58-65. https://doi.org/10.59261/jbt.v6i2.518

INTRODUCTION

Infrastructure development in Indonesia plays a crucial role in supporting economic growth and promoting equitable regional development (Firdatin & Gifary, 2021). One form of strategic infrastructure that significantly contributes to national energy security is coal-based steam power plants (PLTU), many of which are constructed in coastal areas due to logistical and operational considerations (Wollff, 2023). These power plants are essential to meeting the increasing demand for electricity; however, their development presents substantial challenges arising from environmental exposure, site-specific constraints, and complex construction requirements (González-Dueñas & Padgett, 2021; Winarno & Kusumadewi, 2024). A critical issue in such projects is the timely execution of onshore construction works, including coastal protection structures, cooling systems, and major plant installations, all of which require high levels of coordination and precision (González-Dueñas & Padgett, 2021; Kumar, 2024).

Coastal and onshore construction projects are inherently vulnerable to uncertainty due to dynamic environmental conditions, limited accessibility for heavy equipment, and tight interdependencies among construction activities. These characteristics increase exposure to schedule delays and cost overruns if risks are not systematically identified and managed (Afana et al., 2024; Wang et al., 2024). Recent studies emphasize that deficiencies in early-stage planning and risk anticipation remain among the dominant contributors to project underperformance in large-scale infrastructure developments (Leu et al., 2024).

In this context, PT Sabar Sejahtera, a national onshore construction company with extensive experience in both domestic and international projects, was appointed to execute the shore protection works for the Batang 2 × 1000 MW power plant project. Despite this experience, the project suffered a significant three-month delay, which had serious implications for both the project schedule and financial performance (Sharifzada & Deming, 2024; Amoah et al., 2024). The delay was primarily associated with the use of a lump-sum contract, which restricted payment adjustments in response to unforeseen delays, thereby intensifying financial losses borne by the contractor (Irfan et al., 2025). Lump-sum contractual arrangements have frequently been linked to elevated project risk, particularly in environments characterized by high uncertainty, time-sensitive activities, and limited flexibility in scope and cost management (Berends, 2024; Ghamarimajd et al., 2024).

Project delays represent a longstanding challenge within the construction industry (Hossain, 2022). However, delays in coastal and onshore infrastructure projects are typically more complex due to the combined influence of managerial shortcomings, technical constraints, and external environmental factors (Gurgun et al., 2024). In the case of PT Sabar Sejahtera, preliminary observations indicate that the project delay was not caused by a single factor, but rather by systematic errors during the tendering and planning stages, insufficient preparedness for risk, and the absence of a structured risk mitigation framework. Such conditions are consistent with empirical evidence indicating that early-stage decision-making failures often trigger cascading effects throughout the project lifecycle (Afana et al., 2024; Leu et al., 2024).

This situation highlights a broader structural issue within the Indonesian construction sector, where risk management has not yet been fully institutionalized as an integral component of project planning and execution. Many construction firms continue to adopt a reactive approach to risk, responding only after risks materialize and negatively affect project performance (Hohenstein, 2022). In contrast, a proactive risk management approach emphasizing early risk identification, analysis, and mitigation has been widely recognized as a key mechanism for preventing persistent delays and long-term adverse impacts (Leso et al., 2024). Furthermore, advancements in intelligent construction and project management technologies, such as Building Information Modeling (BIM) and data-driven risk assessment tools, have demonstrated strong potential in enhancing planning accuracy, coordination, and schedule reliability in construction projects (Zhang, 2024; Lei et al., 2024). Nevertheless, limited integration of these tools into formal risk management systems continues to constrain their effectiveness in traditional onshore construction environments.

Therefore, this study aims to analyze the root causes of project delays in the shore protection project undertaken by PT Sabar Sejahtera and to design a structured project risk management system as a mitigation strategy for future delays. The findings of this study are expected to provide both theoretical and practical benefits. From a theoretical perspective, this research contributes to the development of risk management literature by integrating system-based analysis tools such as Current Reality Tree (CRT) and Future Reality Tree (FRT) with a PMBOK 6th Edition risk management framework in the context of onshore construction projects. From a practical perspective, the proposed risk management system is intended to serve as a strategic guideline for construction companies, project managers, and policymakers to improve planning accuracy, enhance risk preparedness, reduce schedule delays, and strengthen overall project efficiency and control in complex construction environments in Indonesia (Ghamarimajd et al., 2024).

METHOD

Type of Research

This study adopts an applied research design using a mixed-method approach that integrates qualitative and quantitative techniques. The mixed-method approach was selected to comprehensively analyze project delays by capturing both the systemic and measurable dimensions of risk in onshore construction projects. Qualitative methods enable an in-depth exploration of managerial, organizational, and process-related issues, while quantitative methods provide objective prioritization of risks and support data-driven decision-making.

The qualitative component focuses on identifying the root causes of project delays through stakeholder perspectives and system-based analysis. Meanwhile, the quantitative component is employed to evaluate and rank identified risks using numerical indicators, allowing the formulation of structured and actionable mitigation strategies.

Research Location and Period

The research was conducted at PT Sabar Sejahtera, an Indonesian onshore construction company responsible for the shore protection works of the Batang 2 × 1000 MW coal-fired power plant project in Central Java. This project was selected as a case study due to its documented three-month delay, the availability of comprehensive project records, and direct access to key project stakeholders. The research activities were carried out from January to May 2025, covering the stages of problem identification, data collection, data analysis, and development of risk mitigation recommendations.

Data Sources and Collection Techniques

The study utilizes both primary and secondary data sources to ensure data triangulation and enhance research validity.

1. Primary data were obtained through focus group discussions (FGDs) involving key project stakeholders, including the Project Manager, Operations Director, and Project Coordinator. FGDs were chosen to facilitate interactive discussions, uncover tacit knowledge, and identify interrelated causes of project delays that may not be evident through document analysis alone.
2. Secondary data were collected from internal company documents, including project planning reports, tender documents, Bill of Quantities (BoQ), initial and actual S-curves, work progress reports, and records of changes in work methods and contractual arrangements. These documents provided objective evidence to support qualitative findings and enabled cross-validation of stakeholder perceptions.

Data Analysis Techniques

Data analysis was conducted in several sequential stages to ensure a systematic and comprehensive evaluation of project risks.

1. Qualitative root cause analysis was performed using the Current Reality Tree (CRT) method. CRT was employed to identify the core causes of project delays and to map the cause–effect relationships among various undesirable effects observed during project execution. This approach allowed the identification of systemic issues rather than isolated symptoms.
2. Solution development and impact projection were carried out using the Future Reality Tree (FRT). The FRT was used to visualize how proposed interventions such as improvements in tendering practices and the implementation of structured risk management could positively alter project conditions and reduce the likelihood of future delays.
3. Quantitative risk analysis was conducted using the Failure Mode and Effects Analysis (FMEA) method. Each identified risk was evaluated based on three parameters: severity (S), occurrence (O), and detection (D). The Risk Priority Number (RPN) was calculated using the formula RPN

= S × O × D, and risks were ranked according to their RPN values to determine mitigation priorities. The FMEA approach has been widely validated for construction quality risk evaluation and schedule-related risk assessment (Ma & Wu, 2020).

Risk Mitigation Framework Design

Based on the results of the CRT, FRT, and FMEA analyses, a structured risk mitigation framework was developed using the Project Management Body of Knowledge (PMBOK) 6th Edition as the main reference. The framework encompasses the full risk management cycle, including risk management planning, risk identification, qualitative and quantitative risk analysis, risk response planning, implementation of mitigation measures, and continuous risk monitoring and control.

This integrated methodological approach ensures that the proposed risk management system is not only theoretically grounded but also practically applicable to similar onshore construction projects characterized by high uncertainty and complex stakeholder interactions.

RESULTS AND DISCUSSION

Result

Root Cause Analysis of Project Delay

Group discussions with project stakeholders revealed that the delay in PT Sabar Sejahtera's shore protection project was due to a combination of technical, managerial, and systemic factors. Through the Current Reality Tree (CRT) approach, two leading root causes of delay were found:

1. Systematic errors at the tendering and planning stages, which led to:
   a. Unrealistic budget planning
   b. Inaccurate work schedule, unsuitable vendor selection, and work methods
2. The absence of a structured risk mitigation plan**,** which resulted in:
   a. Delays in procurement of tools and materials
   b. Mid-project change in work method. Inability to respond to dynamic weather and sea conditions
3. The domino effect of these two root causes can be seen in the form of:
   a. Delays in material supply due to emergency procurement
   b. Heavy equipment damage due to lack of maintenance planning, Worker fatigue due to busy schedules and excessive overtime, and Distrust of the main contractor, which led to sudden changes in work methods and sequences

Visualizing the cause structure using CRT made it clear that most of the undesirable effects (UDEs) could be traced back to these two root causes.

Solution Generation: Future Reality Tree (FRT)

Based on the CRT, the research team developed key solutions and projected their impact using the Future Reality Tree (FRT). The agreed key solutions (injections) are:

1. Establish a structured and realistic planning system at the tender stage, including:
   a. Schedule adjustment based on actual field conditions
   b. Cross-departmental involvement in plan development (operations, engineering, finance, procurement)
2. Implement PMBOK 6th Edition-based risk management, including the process of Risk identification, analysis, response, implementation, and monitoring.

The projected positive impacts of implementing the above two solutions include:

1. The project schedule is more adaptive to field risks
2. The risk of delays can be anticipated before they occur. Early and planned procurement of tools and materials can increase trust from the main contractor. Project costs are more controllable, and according to the initial plan

Risk Evaluation Using FMEA

A Failure Mode and Effect Analysis (FMEA) was then conducted to assess key risks and prioritize mitigation strategies. Parameters used:

1. Severity (S): Impact on the project if the risk occurs (1-10)
2. Occurrence (O): Frequency of risk occurrence (1-10)
3. Detection (D): The ability of the system to detect risks before they have an impact (1-10)

Table 1. Example of Risk Analysis Results

Key Risks	Severity	Occurrence	Detection	RPN (S×O×D)
Delay in material procurement	9	8	6	432
Work method error in the field	8	7	5	280
Sudden change of the main contractor	7	6	7	294
Heavy equipment damage	6	5	6	180
Inexperienced labor	8	4	5	160

From the table above, the risk with the highest RPN is the delay in material procurement. This finding aligns with previous qualitative research, which identified the unstructured procurement process as the primary cause of early project delays.

Risk Mitigation Plan

Referring to PMBOK 6th Edition, the mitigation plan is developed through six main stages:

1. Plan Risk Management:
   Develop an SOP for project risk management from the tender stage.
2. Identify Risks:
   Using FGDs and cross-divisional brainstorming to develop an initial risk register.
3. Perform Qualitative and Quantitative Risk Analysis: Classify risks based on probability and impact; assign RPN.
4. Plan Risk Responses:
   Establish mitigation measures for prioritized risks, such as:
   a. Contract vendors with SLA agreements
   b. Create a buffer schedule for materials and heavy equipment to ensure timely delivery. Provide technical training to project workers
5. Implement Risk Responses:
   Engage a dedicated oversight team to ensure that mitigation actions are executed effectively and efficiently.
6. Monitor Risks:
   Develop a risk register and evaluate the impact and effectiveness of mitigation actions every week to ensure ongoing effectiveness.

Discussion

Based on the analysis and comparison with previous studies, this research reveals several significant insights regarding project delay management. First, the findings confirm that project delays are not merely the result of technical deficiencies or operational constraints, but rather originate from weaknesses in comprehensive planning and risk management systems. Inadequate identification of potential risks at the early stages of the project lifecycle often leads to cascading failures, where minor issues escalate into major disruptions. This result aligns with prior studies emphasizing that ineffective risk anticipation and fragmented planning are dominant contributors to project underperformance.

Second, the application of Current Reality Tree (CRT) and Future Reality Tree (FRT) proves to be effective in identifying root causes and systematically mapping improvement strategies. CRT enables organizations to visualize cause-and-effect relationships among existing problems, allowing decision-makers to focus on fundamental issues rather than addressing symptoms. Meanwhile, FRT supports the formulation of future-oriented solutions by illustrating how proposed interventions can transform current undesirable effects into desirable outcomes. The combined use of CRT and FRT strengthens analytical rigor by bridging diagnostic analysis with strategic solution design, offering a holistic framework for project problem-solving.

Third, the use of Failure Mode and Effects Analysis (FMEA) enhances risk prioritization by providing an objective, data-driven mechanism to assess the severity, occurrence, and detectability of potential failures. By calculating the Risk Priority Number (RPN), organizations can allocate resources more efficiently toward high-impact risks. This structured prioritization reduces subjectivity in decision-making and supports proactive mitigation planning. The findings suggest that FMEA is particularly valuable when integrated with systemic analysis tools such as CRT and FRT, as it translates qualitative problem identification into quantitative risk evaluation.

From a practical perspective, the results highlight the critical need for organizations to embed risk management within their project management systems as a core operational function rather than treating it as a static administrative requirement. Risk management should be continuously updated throughout the project lifecycle, supported by regular monitoring, evaluation, and documentation of lessons learned. Such continuous learning mechanisms enable organizations to adapt to dynamic project environments and reduce the likelihood of recurring failures. Consequently, integrating systemic thinking tools and risk-based decision-making frameworks can significantly enhance project resilience, efficiency, and overall performance.

CONCLUSION

The study concluded that the project delay in shore protection works by PT Sabar Sejahtera was caused by a combination of systemic, technical, and managerial factors, with the leading root cause being systematic errors at the tender and planning stages, as well as the absence of a structured risk mitigation system. The problems had far-reaching impacts on project implementation, including supply chain disruptions, damage to heavy equipment, labor fatigue, and a loss of trust from the main contractor. Using the Current Reality Tree and Future Reality Tree approaches, the primary solutions identified were the establishment of a cross-departmental planning system from the project's early stages, as well as the full implementation of a PMBOK-based risk management framework. Quantitative results through FMEA also identified priority risks that required immediate mitigation.

The mitigation plan designed proved to provide strategic and operational direction in preventing similar delays in the future. Overall, this research confirms the importance of integrating risk management at every stage of an onshore construction project, ensuring the timeliness, cost efficiency, and sustainability of working relationships between project stakeholders. It also encourages the adoption of robust, theory-based risk management frameworks to improve decision-making processes and project outcomes, ultimately contributing to more successful and reliable project deliveries in the construction sector.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to PT Sabar Sejahtera for granting access to project data, documentation, and field information that made this research possible. Special appreciation is extended to the Project Manager, Operations Director, and Project Coordinator for their active participation and willingness to share critical insights during the focus group discussions. The authors are also grateful to all project stakeholders who provided valuable perspectives during the data collection process. Furthermore, the authors acknowledge the academic support, methodological guidance, and constructive feedback provided by colleagues and faculty members at Institut Teknologi Bandung, which significantly contributed to the theoretical rigor and practical relevance of this study. This research would not have been completed without their collaborative efforts and professional expertise.

AUTHOR CONTRIBUTION STATEMENT

The Auhtor served as the lead researcher and contributed to the research conceptualization, primary data collection through field observations and stakeholder interviews, comprehensive data analysis using CRT, FRT, and FMEA methods, and initial manuscript drafting. Gatot Yudoko provided essential contributions to the research design, methodological framework development based on PMBOK standards, critical review of analytical approaches, academic supervision throughout the research process, and final manuscript validation. Muhammad Hanafi contributed to advanced data interpretation, validation of research findings through expert assessment, comprehensive manuscript revision for theoretical coherence, and ensuring alignment with international publication standards. All authors have thoroughly read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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