Identification and Evaluation of Risks in Construction Projects in Archipelagic Areas Using Failure Mode Effect And Analysis (FMEA) Methode: A Case Study of East Sumba, Indonesia

Ahmad Farid Ardiansyah[1]
[1] Jurusan Teknik Sipil, Fakultas Teknik, Universitas Jember, 68121
Email : ahmadfarid.teknik@unej.ac.id

Abstract

Construction projects in semi-arid coastal zones operate within complex environmental and managerial constraints that heighten vulnerability to multiple risks. This research analyzes those dynamics through a systematic application of Failure Mode and Effect Analysis (FMEA) to identify, classify, and prioritize critical risk factors affecting project reliability. The results show that material shortages, heat exposure, and unstable energy supply are the most pressing risks, often intensified by weak procurement systems, inaccurate budgeting, and low compliance with environmental and safety protocols.

A comparison of managerial and field-level perceptions reveals notable gaps: while both groups recognize similar degrees of severity, on-site workers view risks as more frequent and difficult to detect, reflecting unequal access to information and experience. When combined, the Probability–Impact Matrix and Risk Priority Number assessment indicate that most hazards fall within the high-risk category.

The study argues that sustainable construction in such climates requires a move from reactive to anticipatory management. It recommends optimizing local resources through adaptive technologies, reinforcing safety culture and workforce skills, and ensuring transparency via digital governance tools. These integrated measures strengthen resilience, operational reliability, and environmental sustainability in resource-constrained construction contexts.

Keywords: *Construction Risk; Semi-arid Regions; FMEA; Probability – Impact Matrix.*

INTRODUCTION

Construction projects in semi-arid coastal regions face a unique combination of environmental and managerial challenges that significantly affect performance, safety, and sustainability (Nabinejad & Schüttrumpf, 2023). These regions are characterized by high temperature fluctuations, limited material availability, and unstable infrastructure networks, which collectively increase operational uncertainty (Sagala et al., n.d.). In such environments, construction processes often experience delays, cost overruns, and reduced workforce productivity, making risk management a central element in achieving project reliability and resilience (Al-Faruq et al., n.d.; Alshihri et al., 2022; Giri, 2025).

While a growing body of research has addressed construction risk assessment in various climatic contexts, studies focusing on semi-arid coastal zones remain limited. Existing frameworks for risk management tend to generalize environmental and socio-technical variables, overlooking the distinct characteristics of regions where climatic stress and resource scarcity intersect (Singh, 2025). Moreover, previous models rarely consider the perception gap between managerial and field-level personnel, despite its critical role in shaping practical risk responses. This gap represents a major research void that hinders the development of adaptive strategies tailored to high-stress environments

To address these limitations, the present study analyzes and prioritizes construction risks specific to semi-arid coastal regions by integrating Failure Mode and Effect Analysis (FMEA) with a Probability–Impact Matrix (Başhan et al., 2020). This dual approach allows for a structured evaluation of risk likelihood, impact, and detectability while visualizing their relative significance within project operations. The study further examines how managerial and field-level perceptions differ in assessing these risks, offering a holistic understanding of the construction risk landscape under environmental stress.

The findings of this research are expected to contribute both theoretically and practically. Theoretically, it advances the discourse on contextual risk management by bridging technical assessment tools with human-centered insights. Practically, it offers a framework that supports decision-making in resource-limited projects, promotes proactive mitigation, and enhances resilience within the construction sector operating in semi-arid coastal conditions.

https://doi.org/10.26740/proteksi.v7n2.p216-227

E-ISSN : 2655-6421

RESEARCH METHODOLOGY

Study Area and Project Overview

The study was conducted in East Sumba Regency, East Nusa Tenggara, Indonesia—an island region situated between approximately 10°00'–10°40' South Latitude and 120°00'–121°00' East Longitude. The selection of this location was grounded in its distinctive geographic and climatic conditions as part of an archipelagic province that experiences logistical difficulties in the distribution of construction materials and the mobilization of labor resources, mainly due to limited road networks and inter-island transport constraint. The research primarily examined infrastructure development projects, particularly road and public building construction, implemented between 2023 and 2024. Furthermore, the identification of this study area was supported by a Land Surface Temperature (LST) analysis derived from satellite-based thermal imagery for the period 2023–2024, which helped pinpoint high-temperature surface zones as the scientific foundation for determining field investigation sites.

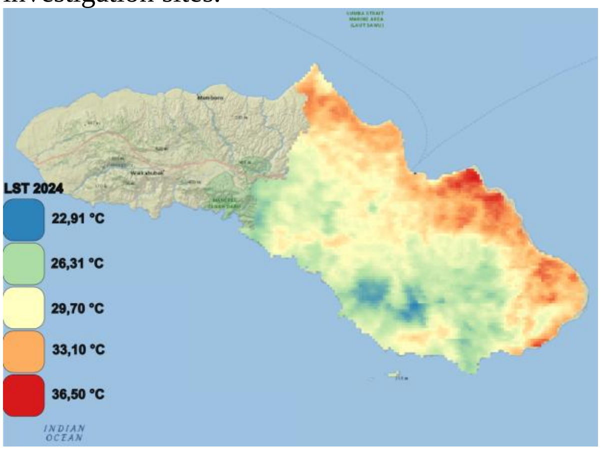

Figure 1. Spatial distribution of Land Surface Temperature (LST) across East Sumba

The Land Surface Temperature (LST) analysis indicates a distinct spatial variation across East Sumba, with the highest surface heat observed along the northern coastline. The red zones on the thermal map correspond to areas of intense heat accumulation, where surface temperatures reached approximately 36.50°C (see Figure 1). This pattern reflects the region's exposure to strong solar radiation and minimal vegetation cover, typical of semi-arid coastal landscapes.

These environmental conditions make East Sumba a representative and strategic site for studying heat-related risks in construction settings. The combination of high surface temperatures, scarce natural resources, and expanding development activities presents unique challenges to worker safety, material durability, and project efficiency. Consequently, East Sumba provides an ideal context for developing adaptive and climate-responsive construction practices in regions facing similar thermal stress conditions.

Data Collection

A descriptive quantitative approach was employed in this study to obtain both statistical and contextual insights into project risks. Data were collected through a combination of structured questionnaires administered to 55 key respondents—comprising contractors, consultants, and project owners—supplemented by in-depth interviews with local engineers and project managers to validate and enrich the survey findings. In addition, a document review of project reports, regional infrastructure records, and supporting technical documentation was conducted to ensure data triangulation and strengthen the reliability of the analysis.

The Failure Mode and Effect Analysis (FMEA) method is a systematic approach to risk assessment that integrates technical analysis with practical experience to identify potential causes of failure within a product or process. Moreover, FMEA serves as a design-oriented methodology aimed at recognizing possible failures during the manufacturing process while evaluating the level of risk associated with each contributing variable.(Budi Puspitasari et al., 2017).

The integration of the Failure Mode and Effect Analysis (FMEA) technique with the ISO 31000:2018 risk management framework provides a comprehensive and structured approach to identifying, analyzing, and mitigating project risks (International Organization for Standardization, 2018). The following steps outline the process that can be applied in construction project risk assessment:

a. Establishing the Context. The first stage, aligned with ISO 31000 (International Organization for Standardization, 2018), involves defining the internal and external environment of the project, including its objectives, scope, stakeholders, and operating conditions. For construction projects in archipelagic areas, this includes geographic, logistical, and climatic factors that may influence project performance.
b. Risk Identification Potential failure modes are identified through FMEA by examining each component or process of the project to determine how and where failures might

https://doi.org/10.26740/proteksi.v7n2.p216-227

E-ISSN : 2655-6421

occur. This step is enriched by stakeholder consultation and document review, as recommended in ISO 31000, to ensure all relevant risks are captured.

c. Risk Analysis, In this phase, each identified failure mode is evaluated in terms of severity, occurrence, and detection, leading to the calculation of the Risk Priority Number (RPN). The RPN helps quantify and prioritize risks. The ISO 31000 principles of evidence-based and structured analysis are applied to ensure consistency and transparency in evaluation.
d. Risk Evaluation The RPN values are compared against the project's acceptable risk criteria to determine which risks require treatment. ISO 31000 emphasizes that this evaluation should be aligned with the organization's risk appetite and decision-making framework.
e. Assign numerical scores or priority ratings for severity, occurrence, and detection of each potential failure on a scale from 1 to 10, with 10 representing the greatest level of severity, likelihood, or difficulty of detection.

Data on risk perception and intervention effectiveness were collected through three primary instruments: data sheets for construction workers, structured questionnaires and interview guides for managerial personnel, and on-site observation checklists. The questionnaire items were developed based on key references and aligned with the ISO 31000:2018 (International Organization for Standardization, 2018) framework, which emphasizes the identification of both external and internal factors influencing construction project performance. External factors generally stem from environmental, climatic, and regulatory conditions beyond the project's direct control, whereas internal factors are associated with management practices, planning accuracy, supervision, and workforce competency. Understanding these two dimensions of risk is essential for designing effective mitigation strategies, particularly in East Sumba, where geographical isolation, limited infrastructure, and extreme climatic conditions create unique challenges for construction activities.

Table 1. Risk Factor and Potensial Impact

No	Category	Risk Factor	Potential Impact	Reference
1	**External**	Extreme temperature and heat stress	Worker fatigue, decreased productivity, health issues	(International Organization for Standardization, 2018); (Liu et al., 2018)
2	**External**	Limited water availability / drought	Poor concrete curing, project delays	(International Organization for Standardization, 2015);(Salah A. Sheibani, 2024)
3	**External**	Heavy rainfall or local storms	Damage to temporary structures, schedule disruption	(Jae-Seob, 2016)
4	**External**	Strong wind and open exposure	Material damage, safety hazards	(Yang & Bai, 2017)
5	**External**	Poor transportation access	Late material delivery	(Khursheed et al., 2024)
6	**External**	Limited local material supply	Cost escalation, quality inconsistency	(Muya et al., 2013)
7	**External**	Power and fuel supply disruption	Equipment downtime	(Panova & Hilletofth, 2018)
8	**External**	Regulatory and permit delays	Schedule suspension	(Wijesuriya & Sugathadasa, 2025)
9	**External**	Social and community conflict	Project interruption, stakeholder dissatisfaction	(G. Jia et al., 2011)
10	**Internal**	Inadequate project supervision	Quality deviation, cost overrun	(Gong et al., 2017)
11	**Internal**	Unrealistic cost estimation (RAB)	Budget deficit, rework	(Khodakarami & Abdi, 2014)
12	**Internal**	Limited skilled labor	Low productivity, high error rates	(Hossein et al., 2018)
13	**Internal**	Weak safety culture (K3)	Accident risks, project disruption	(DeJoy, 2005)
14	**Internal**	Inefficient procurement	Delay in project progress	(Hong Pham & Hadikusumo, 2014)
15	**Internal**	Poor communication among project teams	Coordination failure, slow decisions	(Wu et al., 2017)
16	**Internal**	Low compliance with environmental standards	Legal risk, reputational damage	(Lange, 1999) ; (Tam et al., 2006)

https://doi.org/10.26740/proteksi.v7n2.p216-227

E-ISSN : 2655-6421

Analysis Method

Failure Mode and Effect Analysis (FMEA) is recognized as a preventive methodology aimed at minimizing or eliminating potential failures by addressing their underlying causes. This approach seeks to ensure that similar failures do not occur in the future. The implementation of FMEA generally involves three main stages (Ariany et al., 2023; Başhan et al., 2020; Bhattacharjee et al., 2020).

1. Failure Identification – determining possible errors or weaknesses that may arise within a process;
2. Failure Prioritization – assessing and ranking the identified failures based on their level of risk, typically using the Risk Priority Number (RPN);
3. Reduce Risk – applying appropriate strategies or actions to reduce the level of identified risks.

In the (FMEA) approach, the Risk Priority Number (RPN) is determined based on three key components: Occurrence (O), Severity (S), and Detection (D) (Bhattacharjee et al., 2020). Each of these parameters serves a distinct role in evaluating potential risks:

1. Occurrence (O): refers to the likelihood or frequency with which a specific failure or risk event may happen.
2. Severity (S): represents the magnitude or seriousness of the potential impact that the failure may have on the process or system performance.
3. Detection (D): denotes the capability of monitoring, inspection, or testing mechanisms to identify defects or failure modes before they result in adverse outcomes.

A higher detection rating signifies a greater likelihood that the failure will go unnoticed or remain undetected. Conversely, lower detection values indicate a stronger ability of the system to identify potential failures before they occur.

Table 2. Risk Level Assesment (Maruf et al., 2017)

Score	Occurrence	Severity	Detection
1	Very unlikely to occur	Very low, will not affect the process	Almost certain – the fault will be detected during testing
2–3	Unlikely to occur	Low, may affect the process	High likelihood of detection
4–5	May occur about half of the time	Medium, slightly affects the process	Moderate likelihood of detection
6–7–8	Likely to occur	High, mostly affects the process	Low likelihood of detection
9–10	Very likely to occur	Very high, definitely affects the process	The fault will reach the customer undetected

The table illustrates the risk assessment levels used in the FMEA approach, where each potential failure is evaluated based on three key factors: occurrence, severity, and detection. The occurrence score reflects how often a failure may happen, while the severity score indicates the magnitude of its impact on the process. The detection score represents how effectively the failure can be identified before causing harm. Higher occurrence and severity values combined with low detection capability indicate greater risk, helping researchers and practitioners prioritize corrective and preventive measures more effectively.

Once all factors have been identified, the Risk Priority Number (RPN) is calculated by multiplying the values of Severity (S), Occurrence (O), and Detection (D).

$$RPN = Severity\ x\ Occorrence\ x\ Detection \quad (1)$$

The data sampling process applied a stratified approach based on two main criteria. The first criterion targeted primary job categories that are particularly vulnerable to risk, such as steel fixers, carpenters, concrete laborers, masons, plasterers, welders, scaffolders, mechanical and electrical technicians, and demolition crews. The second criterion included individuals at the managerial and supervisory levels, comprising project directors, site managers, safety supervisors, and quality control staff, who play a key role in managing site operations and ensuring adherence to safety and performance standards. At every construction location, a group of 5 to 10 workers was selected to take part in the study. Over the course of two consecutive working days, research assistants conducted two sessions with the participants — one held before work began and another after the workday ended — while the workers continued their usual activities between sessions. To maintain a natural and comfortable atmosphere, the interviews were conducted

https://doi.org/10.26740/proteksi.v7n2.p216-227

E-ISSN : 2655-6421

informally without the use of any video or audio recording devices. The sampling process was structured according to the Work Breakdown Structure (WBS), aligning with the project's scheduled phases of implementation.

Table 3. Data Collection Protocol

	Work session	Day Time	After work
Day 1	**Introduction** (Eksternal Fator Risk)	Continous recording at work place	Interviews Worker
Day 1	**Night (Rest Activity)** (Internal Factor Risk)	*Worker fill questionnaires at home after work*	Personal baseline data
Day 2	**Collect Completed Questionnaires and interview** (Eksternal and Internal Factor Risk)	Continuous Report and recording	Semi Structure Interview

RESULTS AND DISCUSSION

Identified Risk Factors

Risk management plays a crucial role in project implementation, encompassing several essential stages such as risk identification, risk assessment, and risk mitigation. The initial stage focuses on identifying potential risks that may arise and cause adverse impacts on project performance. This process was conducted through an extensive literature review—drawing from relevant studies (see table 1) —and field observations during construction activities. The analysis followed the principles outlined in ISO 31000:2018 on Risk Management, which emphasizes a systematic and structured approach to identifying both internal and external risks. Based on these analyses and on-site evaluations, the identified risks were categorized accordingly, as summarized in the following table 4.

Table 4. Risk Factor and Potensial Impact

Code	Risk Type	Risk Description
R01	Environmental Risk	High rainfall may disrupt the project schedule and cause damage to temporary structures.
R02	Environmental Risk	Extreme temperatures and heat stress may affect workers' productivity and health conditions on site.
R03	Environmental Risk	Strong winds in open coastal areas may cause material loss and pose safety hazards.
R04	Environmental Risk	Limited water availability in semi-arid regions may impact concrete curing and delay construction activities.
R05	Resource Risk	Limited availability of skilled labor may result in decreased work quality and project delays.
R06	Resource Risk	Scarcity of local materials may increase project costs and lead to quality inconsistency.
R07	Resource Risk	Unreliable power and fuel supply may interrupt machinery operation and reduce work efficiency.
R08	Managerial Risk	Inadequate project supervision may result in quality deviations and cost overruns.
R09	Managerial Risk	Poor communication among project teams may lead to coordination failures and delayed decision-making.
R10	Managerial Risk	Inefficient procurement processes may delay material delivery and project progress.
R11	Managerial Risk	Lack of planning accuracy may cause schedule slippage and rework.
R12	Financial Risk	Unrealistic cost estimation may lead to budget deficits and the need for rework.
R13	Financial Risk	Fluctuation in material prices and logistics costs may increase total project expenditure.
R14	Regulatory Risk	Delays in obtaining project permits may suspend or postpone construction activities.
R15	Regulatory Risk	Frequent changes in government policies may affect project compliance and approval timelines.
R16	Social Risk	Conflicts with local communities may disrupt project progress and reduce social acceptance.

https://doi.org/10.26740/proteksi.v7n2.p216-227

 E-ISSN : 2655-6421

Code	Risk Type	Risk Description
R17	Social Risk	Lack of stakeholder engagement may lead to dissatisfaction and resistance during implementation.
R18	Occupational Health and Safety (OHS) Risk	Weak safety culture may increase the likelihood of workplace accidents and project disruptions.
R19	Occupational Health and Safety (OHS) Risk	Insufficient use of personal protective equipment (PPE) may lead to severe injuries among workers.
R20	Environmental Management Risk	Low compliance with environmental standards may cause legal issues and damage the project's reputation.

Calculation of Risk Priority

The Risk Priority Number (RPN) was determined by multiplying the mean values of each identified risk source to obtain the RPN score for every specific risk event. The assessment was conducted using inputs from both field workers and individuals at the managerial and supervisory levels, including project directors, site managers, safety officers, and quality control personnel. This multi-level evaluation provided a comprehensive representation of perceived risks across different roles within the construction project. The summarized results of the RPN calculations for each risk event are presented in Table 5.

Table 5. Average of occurrence (O), severity (S) and detection (D) risk assessment

No	Code	Risk Type	O	S	D	RPN (O×S×D)
1	R01	Heavy rainfall disruptions	6,02	5,07	5,83	178,10
2	R02	Extreme temperatures / Heat stress (thermal)	8,98	7,99	7,17	514,00
3	R03	Strong coastal winds	4,90	6,03	4,93	145,87
4	R04	Limited water availability	6,98	6,99	5,90	287,72
5	R05	Limited skilled labour	6,23	5,98	4,65	172,92
6	R06	Scarcity of local materials (logistics)	8,95	8,89	7,65	609,12
7	R07	Unreliable power / fuel supply	7,19	5,94	5,74	245,34
8	R08	Inadequate supervision	4,90	5,92	4,41	127,79
9	R09	Poor communication	5,86	5,01	4,50	132,11
10	R10	Inefficient procurement	4,85	6,14	4,88	145,34
11	R11	Lack of planning accuracy	4,76	4,95	4,54	106,88
12	R12	Unrealistic cost estimation	6,19	6,85	4,68	198,32
13	R13	Price & logistics cost fluctuation	6,90	5,99	5,55	229,60
14	R14	Permit delays	6,17	6,00	5,01	185,33
15	R15	Frequent policy changes	5,10	5,89	4,38	131,48
16	R16	Conflicts with local communities	5,66	5,93	5,54	185,79
17	R17	Lack of stakeholder engagement	5,10	5,13	4,52	118,26
18	R18	Weak safety culture (OHS)	5,87	7,92	5,61	260,99
19	R19	Insufficient PPE use	5,39	7,04	4,70	178,04
20	R20	Low compliance with environmental standards	5,68	7,08	6,02	242,10

The compiled dataset captures the results of risk assessments based on Occurrence (O), Severity (S), and Detection (D) indicators across 20 identified construction-related risks. Responses were obtained from two distinct respondent groups—site workers (n = 40) and managerial or supervisory personnel (n = 15)—allowing for a comparative analysis of risk perception across operational hierarchies. The analysis indicates that logistical and environmental constraints constitute the most significant sources of construction risk in semi-arid coastal regions. In particular, the scarcity of locally available materials and thermal stress arising from extreme ambient temperatures stand out as the two most influential contributors to overall risk intensity. These are followed by challenges associated with price and logistics cost fluctuations and unstable power or fuel supply. In contrast, risks linked to policy dynamics, planning accuracy, and site supervision exhibit relatively lower weighted scores, suggesting stronger

https://doi.org/10.26740/proteksi.v7n2.p216-227

 E-ISSN : 2655-6421

management control or lower perceived severity in those domains.

Figure 2. Distribution of Risk Priority Numbers (RPN)

The independent samples t-test indicated significant differences between workers and managerial staff in terms of risk occurrence (t(1098) = –7.002, p < .001, d = –0.47) and detection (t(1098) = –9.673, p < .001, d = –0.65). However, no statistically significant difference was observed for severity (t(1098) = –0.512, p = 0.609, d = –0.03). These results suggest that while both groups share a similar perception of the potential impact of risks, workers perceive risks as more frequent and less detectable, highlighting the need for enhanced field-level awareness and monitoring mechanisms in semi-arid construction environments. (See Table 6)

Table 6. Independent Samples T-Test

		Statistic	df	p		Effect Size
Occurrence	**Student's t**	-7.002	1098	<.001	Cohen's d	-0.4740
Severity	**Student's t**	-0.512[a]	1098	0.609	Cohen's d	-0.0347
Detection	**Student's t**	-9.673[a]	1098	<.001	Cohen's d	-0.6549

Note. H_a μManagerial ≠ μWorker

[a] Levene's test is significant (p < .05), suggesting a violation of the assumption of equal variances

https://doi.org/10.26740/proteksi.v7n2.p216-227

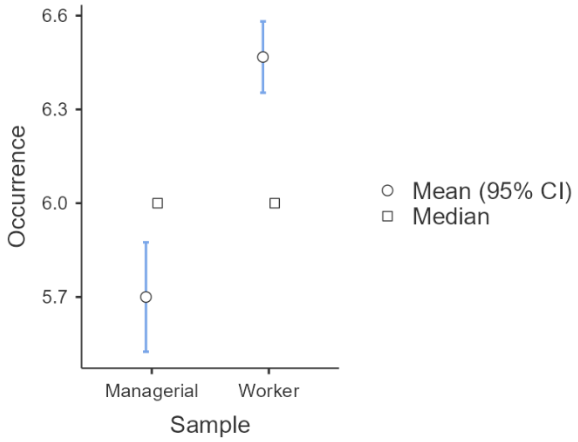

Figure 3. Descriptives Plots Occurrence

As illustrated in Figure 3, the results show Field workers tend to perceive risks as occurring more frequently compared to managerial personnel. This difference likely arises from their direct and continuous exposure to on-site conditions such as igh temperatures, logistical disruptions, and equipment-related hazards. Their firsthand experience with these challenges shapes a heightened sense of vulnerability, leading to a more tangible awareness of operational risks in daily construction activities.Field workers tend to perceive risks as occurring more frequently compared to managerial personnel. This difference likely arises from their direct and continuous exposure to on-site conditions such as high temperatures, logistical disruptions, and equipment-related hazards. Their firsthand experience with these challenges shapes a heightened sense of vulnerability, leading to a more tangible awareness of operational risks in daily construction activities.

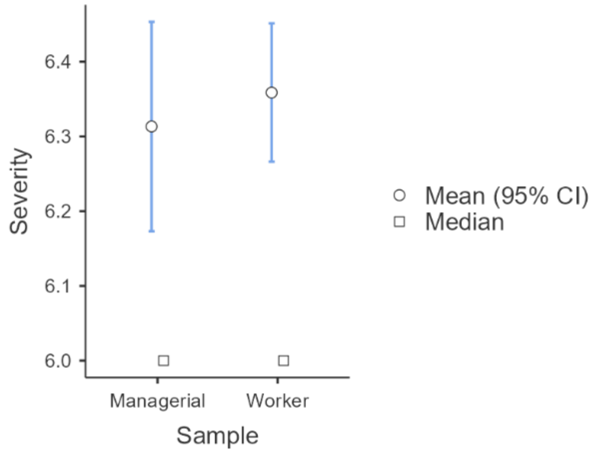

Figure 4. Descriptives Plots Severity

In Figure 4 Both workers and managerial personnel exhibit a comparable perception of risk severity, indicating a shared understanding of how potential hazards may impact project performance. This alignment suggests that, despite differences in roles and exposure, both groups recognize the critical consequences of key risks, particularly those related to safety, material availability, and environmental conditions. Such convergence in perception provides a strong foundation for developing unified mitigation strategies across organizational levels.

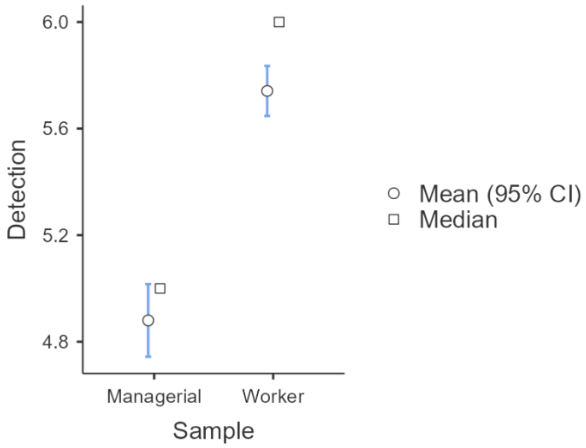

Figure 5. Descriptives Plots Detection

As shown in Figure 5, there is a notable gap between workers and managerial staff in risk detection capability. Managerial personnel tend to identify early warning signs more effectively, supported by structured monitoring systems and broader project oversight. In contrast, field workers are less responsive to subtle indicators of risk, as their attention is directed toward immediate operational tasks. This finding highlights the need to strengthen communication and on-site training to improve workers' awareness and integrate practical field experience with formal risk management practices.

Risk Evaluation

The Probability–Impact Matrix provides a visual structure for assessing both the likelihood and potential impact of identified risks. Risks are grouped into three categories—low, medium, and high. Low risks, shown in green, occupy the lower-left diagonal, representing acceptable conditions. High risks, displayed in red at the upper-right corner, indicate critical threats that must be minimized or avoided, while yellow zones reflect moderate risks lying between the two extremes.

The results derived from this matrix are consistent with the prioritization produced by the Failure Mode and Effect Analysis (FMEA) through Risk Priority Number (RPN) scoring. The RPN

https://doi.org/10.26740/proteksi.v7n2.p216-227

 E-ISSN : 2655-6421

values can be plotted onto the 5×5 matrix to illustrate how probability and impact interact in determining overall risk intensity.

Unlike FMEA, however, the matrix considers only two dimensions—severity and likelihood—excluding the detection factor. This simplification makes the tool easier to apply for project-level risk visualization. Based on the average values of severity and occurrence, the Probability–Impact Matrix illustrates the dominant risk areas and supports the formulation of targeted mitigation strategies in construction projects.

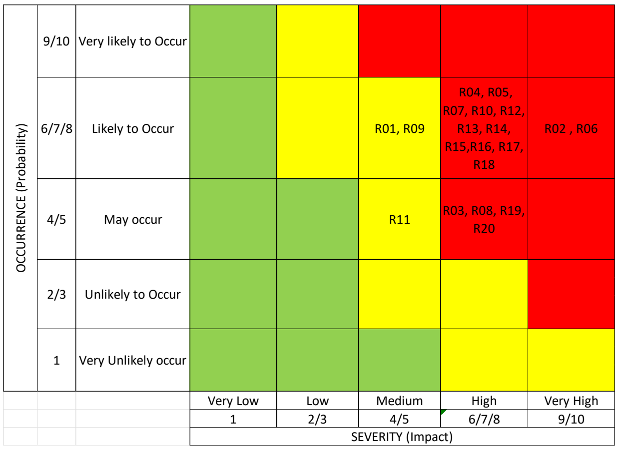

Figure 6. Probability Impact Matrix

Discussion of Findings

The probability–impact evaluation indicates that most of the identified risks are concentrated in the high-risk zone of the matrix. These include limited water availability (R04), shortage of skilled labour (R05), unreliable power or fuel supply (R07), inefficient procurement systems (R10), unrealistic cost estimation (R12), price and logistics cost fluctuation (R13), permit delays (R14), frequent policy changes (R15), conflicts with local communities (R16), lack of stakeholder engagement (R17), and weak safety culture (R18).

The dominance of these items suggests that construction projects in semi-arid coastal regions are exposed to a combination of environmental constraints and management-related vulnerabilities that are not yet adequately controlled.

From an environmental standpoint, the scarcity of water and energy illustrates a strong dependence on natural resources that are inherently unstable in such regions. This condition directly influences productivity, scheduling, and operational continuity. Human resource issues, such as the limited availability of skilled workers and weak occupational safety practices, further complicate project performance, potentially increasing accident rates and reducing work quality. Administrative factors, including regulatory delays and frequent policy adjustments, intensify uncertainty and may extend project timelines or inflate costs. In addition, inefficiencies in procurement, inaccurate cost forecasting, and market price volatility indicate systemic weaknesses in financial and logistical planning.

Risks classified as moderate—namely heavy rainfall disruptions (R01), poor communication (R09), and lack of planning accuracy (R11)—are manageable yet require close observation. Although they pose less immediate danger, their cumulative impact can aggravate other risk clusters. For instance, poor communication between project teams can delay decision-making, reduce coordination efficiency, and indirectly contribute to procurement or scheduling problems. Similarly, inaccurate planning may trigger cascading effects on budgeting and progress control.

Several other risks, including strong coastal winds (R03) and inadequate supervision (R08), fall near the upper boundary of the high-risk area. These findings point to the strong interaction between environmental stressors and management capacity. The coexistence of natural hazards—such as extreme heat, wind, and rainfall—with human-related weaknesses emphasizes the multidimensional nature of construction risks in coastal environments

Recommended Mitigation Strategies

Overall, the distribution pattern of risks reveals that the studied project operates within an ecosystem characterized by limited resource resilience, unstable regulatory frameworks, and underdeveloped managerial adaptability. This configuration implies that the current risk management framework is largely reactive and insufficiently contextualized.

To address these issues, three key strategies are recommended:

1. Resource management optimization, for example through water-recycling systems and substitution of local materials;
2. Capacity building and safety culture improvement, involving regular training and field supervision programs; and
3. Enhanced governance and digital monitoring, aimed at improving procurement transparency, stakeholder coordination, and regulatory compliance.

By integrating these measures, project resilience can be substantially improved while

https://doi.org/10.26740/proteksi.v7n2.p216-227

aligning construction practices with sustainable development principles suited for regions facing climatic and logistical challenges. Ultimately, the analysis underscores the need for a context-sensitive and adaptive risk management model, one that acknowledges the interplay between environmental and organizational dimensions in determining project performance.

CONCLUSION

This research explores the structure and distribution of construction-related risks in semi-arid coastal regions through a systematic application of Failure Mode and Effect Analysis (FMEA). The findings reveal that environmental and logistical challenges dominate the overall risk profile, particularly those related to material shortages, heat stress, and unstable energy supply. These high-priority risks are further exacerbated by managerial inefficiencies, including weak procurement systems, inaccurate cost estimations, and low adherence to safety and environmental regulations. Collectively, these conditions highlight the fragile operational ecosystem that characterizes construction projects in semi-arid coastal environments.

The comparative analysis between site workers and managerial personnel offers valuable insights into internal perception gaps within project organizations. Field workers, being directly exposed to climatic and operational hazards, tend to perceive risks as more frequent and harder to detect than their managerial counterparts. Although both groups show similar awareness regarding risk severity, the differing perceptions of frequency and detectability emphasize the need for stronger communication frameworks, participatory safety initiatives, and more decentralized decision-making in monitoring and managing risks.

The integration of the Probability–Impact Matrix with RPN-based prioritization confirms that construction projects in semi-arid regions must transition from a reactive to a proactive and anticipatory approach to risk management. To support this shift, three key strategies are proposed, Optimizing resource utilization through adaptive technologies and the use of locally available materials. Then Enhancing safety culture and workforce competence via continuous training and on-site supervision; and Establishing transparent governance structures supported by digital monitoring systems to improve procurement accountability, stakeholder coordination, and regulatory compliance.

These strategies serve both preventive and strategic purposes, embedding resilience and sustainability into everyday construction practices.

Ultimately, effective risk management in semi-arid coastal construction requires more than formal compliance—it demands contextual intelligence that integrates environmental awareness, organizational flexibility, and stakeholder collaboration. By adopting a holistic and site-responsive risk framework, project stakeholders can strengthen operational reliability, reduce vulnerability to climatic extremes, and promote sustainable infrastructure development in regions where environmental and resource constraints are most severe.

REFERENCE

Al-Faruq, U., Sagala, S., Rianawati, E., Currie, E., & Al Faruq, U. (n.d.). *Working Paper Series Assessment of Renewable Energy Impact to Community Resilience in Sumba Island Editorial Team: Assessment of Renewable Energy Impact to Community Resilience in Sumba Island **.

Alshihri, S., Al-gahtani, K., & Almohsen, A. (2022). Risk Factors That Lead to Time and Cost Overruns of Building Projects in Saudi Arabia. *Buildings*, *12*(7). https://doi.org/10.3390/buildings12070902

Ariany, Z., Pitana, T., & Vanany, I. (2023). RISK ASSESSMENT OF NEW FERRY SHIP CONSTRUCTION IN INDONESIA USING THE FAILURE MODE EFFECT AND ANALYSIS (FMEA) METHOD. *Journal of Applied Engineering Science*, *21*(3), 872–883. https://doi.org/10.5937/jaes0-43711

Başhan, V., Demirel, H., & Gul, M. (2020). An FMEA-based TOPSIS approach under single valued neutrosophic sets for maritime risk evaluation: the case of ship navigation safety. *Soft Computing*, *24*(24), 18749–18764. https://doi.org/10.1007/s00500-020-05108-y

Bhattacharjee, P., Dey, V., & Mandal, U. K. (2020). Risk assessment by failure mode and effects analysis (FMEA) using an interval number based logistic regression model. *Safety Science*,

https://doi.org/10.26740/proteksi.v7n2.p216-227

132. https://doi.org/10.1016/j.ssci.2020.104967

Budi Puspitasari, N., Padma Arianie, G., & Adi Wicaksono, P. (2017). ANALISIS IDENTIFIKASI MASALAH DENGAN MENGGUNAKAN METODE FAILURE MODE AND EFFECT ANALYSIS (FMEA) DAN RISK PRIORITY NUMBER (RPN) PADA SUB ASSEMBLY LINE (Studi Kasus : PT. Toyota Motor Manufacturing Indonesia). In *Jurnal Teknik Industri* (Vol. 12, Issue 2).

DeJoy, D. M. (2005). Behavior change versus culture change: Divergent approaches to managing workplace safety. *Safety Science*, *43*(2), 105–129. https://doi.org/https://doi.org/10.1016/j.ssci.2005.02.001

Giri, O. P. (2025). Assessment of Key Risk Factors Impacting Construction Project Performance. *International Journal of Multidisciplinary Research and Growth Evaluation*, *6*(1), 1231–1241. https://doi.org/10.54660/.ijmrge.2025.6.1.1231-1241

Gong, C., Zhang, H., Yang, J., & Tao, D. (2017). Learning with Inadequate and Incorrect Supervision. *2017 IEEE International Conference on Data Mining (ICDM)*, 889–894. https://doi.org/10.1109/ICDM.2017.110

Hong Pham, L., & Hadikusumo, H. (2014). Schedule delays in engineering, procurement, and construction petrochemical projects in Vietnam: A qualitative research study. *International Journal of Energy Sector Management*, *8*(1), 3–26. https://doi.org/10.1108/IJESM-06-2013-0009

Hossein, K., B, T. T. R., B, D. G., M, G. P., & Cidambi, S. (2018). Impact of Skilled Labor Availability on Construction Project Cost Performance. *Journal of Construction Engineering and Management*, *144*(7), 04018057. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001512

International Organization for Standardization. (2015). *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use*. https://www.iso.org/standard/60857.html

International Organization for Standardization. (2018). *ISO 31000:2018 – Risk Management: Guidelines*. https://www.iso.org/standard/65694.html

Jae-Seob, L. (2016). Estimating Cumulative Damages due to Disruptions in Repetitive Construction. *Journal of Construction Engineering and Management*, *142*(11), 04016064. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001184

Jia, G., Yang, F., Wang, G., Hong, B., & You, R. (2011). A study of mega project from a perspective of social conflict theory. *International Journal of Project Management*, *29*(7), 817–827. https://doi.org/10.1016/j.ijproman.2011.04.004

Khodakarami, V., & Abdi, A. (2014). Project cost risk analysis: A Bayesian networks approach for modeling dependencies between cost items. *International Journal of Project Management*, *32*(7), 1233–1245. https://doi.org/10.1016/j.ijproman.2014.01.001

Khursheed, S., Sharma, S., Paul, V. K., Alzubaidi, L. H., & Israilova, D. (2024). Review of the Factors Inducing Delay in Construction Project Material Management. *E3S Web of Conferences*, *563*. https://doi.org/10.1051/e3sconf/202456302044

Lange, Bettina. (1999). Compliance Construction in the Context of Environmental Regulation. *Social & Legal Studies*, *8*(4), 549–567. https://doi.org/10.1177/a010430

Liu, X., Tang, Q., Zhang, X., & Sun, S. (2018). Projected Changes in Extreme High

Temperature and Heat Stress in China. *Journal of Meteorological Research*, *32*(3), 351–366. https://doi.org/10.1007/s13351-018-7120-z

Maruf, B., Prihandono, M., Syairudin, B., & Ma'ruf, B. (2017). *SHIPBUILDING RISKS ANALYSIS (CASE STUDY OF NEW BUILD PERTAMINA TANKER 3.500 DWT ON PT. DUMAS TANJUNG PERAK SHIPYARDS)*. https://www.researchgate.net/publication/325319674

Muya, M., Kaliba, C., Sichombo, B., & Shakantu, W. (2013). Cost Escalation, Schedule Overruns and Quality Shortfalls on Construction Projects: The Case of Zambia. *International Journal of Construction Management*, *13*(1), 53–68. https://doi.org/10.1080/15623599.2013.10773205

Nabinejad, S., & Schüttrumpf, H. (2023). Flood Risk Management in Arid and Semi-Arid Areas: A Comprehensive Review of Challenges, Needs, and Opportunities. In *Water (Switzerland)* (Vol. 15, Issue 17). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/w15173113

Panova, Y., & Hilletofth, P. (2018). Managing supply chain risks and delays in construction project. *Industrial Management & Data Systems*, *118*(7), 1413–1431. https://doi.org/10.1108/IMDS-09-2017-0422

Sagala, S. A., Lassa, J., & Arrafisena, F. (n.d.). *Insights from Sumba: Compilation of Ideas on Adaptive Social Protection against Climate Change*.

Salah A. Sheibani. (2024). THE IMPACT OF ENVIRONMENTAL FACTORS ON CONSTRUCTION BUILDINGS IN LIBYA. *Malaysian Journal of Industrial Technology*, *8*(3), 29–38. https://doi.org/https://doi.org/10.70672/xfjbm376

Singh, J. (2025). Risk Assessment and Mitigation in Construction Building Projects. *Journal of Construction and Building Materials Engineering*, *11*(1), 14–23. https://doi.org/10.46610/jocbme.2025.v011i01.002

Tam, V. W. Y., Tam, C. M., Zeng, S. X., & Chan, K. K. (2006). Environmental performance measurement indicators in construction. *Building and Environment*, *41*(2), 164–173. https://doi.org/https://doi.org/10.1016/j.buildenv.2005.01.009

Wijesuriya, R., & Sugathadasa, N. (2025). Causes of Building Permit Delays: A Case Study of a Sri Lankan Local Government Authority. *Journal of Real Estate Studies*, *22*(2), 16–29. https://doi.org/10.31357/jres.v22i2.8270

Wu, G., Liu, C., Zhao, X., & Zuo, J. (2017). Investigating the relationship between communication-conflict interaction and project success among construction project teams. *International Journal of Project Management*, *35*(8), 1466–1482. https://doi.org/https://doi.org/10.1016/j.ijproman.2017.08.006

Yang, N., & Bai, F. (2017). Damage analysis and evaluation of light steel structures exposed to wind hazards. In *Applied Sciences (Switzerland)* (Vol. 7, Issue 3). MDPI AG. https://doi.org/10.3390/app7030239