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Systemic risk of tender failures in government projects: An FMEA-based analysis of price deviation impacts on infrastructure preparedness

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ABSTRACT
Background: Infrastructure preparedness during disasters depends greatly on the successful and timely execution of government construction projects, particularly multi-story buildings that function as critical public facilities. However, in practice, many of these projects experience tender failures due to significant price deviations from the Owner's Estimate (HPS), either through underpricing or overpricing. These failures often result in delays or cancellations, disrupting the availability of essential infrastructure in emergency scenarios. **Methods:** This study applies the Failure Mode and Effect Analysis (FMEA) method to systematically identify, assess, and prioritize the underlying causes of tender failure in a government-funded multi-story building project. Data collection involved document analysis, expert validation, and structured questionnaires focusing on three key parameters: severity, occurrence, and detection of each failure mode. **Findings:** The results reveal two major categories of failure factors: issues related to documentation and problems in cost estimation. Documentation issues include unclear specifications and lack of expert personnel due to limited preparation time, while cost estimation problems involve insufficient market analysis, unrealistic pricing, and scheduling errors. The highest Risk Priority Numbers (RPNs) were found in the indicators "failure in offering strategy" (RPN = 22.944), "failure in prequalification" (RPN = 22.874), and "lack of expert personnel due to limited time availability" (RPN = 22.032), all of which are considered critical and indicative of systemic vulnerability in the tendering process. These critical failures highlight the potential risk they pose to infrastructure readiness, especially in disaster-prone contexts. **Conclusion:** Tender failures caused by price deviation pose a systemic risk to infrastructure preparedness. Reforming public procurement systems with improved risk identification and mitigation strategies—especially in document and cost estimation processes—is essential for supporting disaster-resilient infrastructure development. **Novelty/Originality of this article:** This study is one of the first to link FMEA-based tender risk assessment with disaster preparedness outcomes, offering a novel contribution to both construction management and resilience planning.

KEYWORDS: cost estimation; disaster-resilient infrastructure; FMEA; price deviation; tender documents; tender failure.

1. Introduction

The construction of multi-story buildings by the government is a fundamental component in supporting public services and enhancing disaster preparedness. Such buildings often serve as strategic facilities, including hospitals, emergency response offices, evacuation centers, or other essential public service infrastructures. In many countries, adequate infrastructure development forms the foundation for sustainable social and economic progress. Specifically, multi-story buildings as part of urban infrastructure play a

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critical role in delivering public services. These buildings must not only fulfill functional requirements but also demonstrate resilience and adaptability to various disaster threats such as earthquakes, floods, and tsunamis (Misanova et al., 2020; Negi, 2021).

Resilient infrastructure is a key enabler of effective disaster risk reduction and aligns with global goals like the Sendai Framework and the Sustainable Development Goals (SDGs), especially SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities). In disaster-prone areas, facilities like hospitals, emergency command centers, and evacuation shelters must be delivered on time to serve their intended functions. Procurement-related delays can severely compromise national disaster preparedness and resilience strategies (Palinkas et al., 2021; Rajesh & Keshav, 2022). Infrastructure must not only be designed to withstand physical hazards but also be available when needed. Therefore, procurement efficiency is directly linked to disaster risk management effectiveness.

Disaster preparedness is a critical component of risk management systems, heavily reliant on the ability of infrastructure to remain operational during emergencies (Palinkas et al., 2021). Multi-story buildings, especially those designated as safe zones or evacuation centers, must be designed with comprehensive considerations of technical, structural, and operational aspects to ensure resilience and continuity of function during disasters. Well-designed infrastructure plays a strategic role in mitigating the impact of disasters and accelerating evacuation and post-disaster recovery (Saifudin, 2023). Therefore, beyond adaptive architectural design, it is essential to ensure that such buildings can function optimally in emergency scenarios, including aspects of accessibility, seismic resistance, and the reliability of supporting systems such as water, electricity, and communication networks (Patrisina et al., 2018).

Timely completion of infrastructure projects is crucial to ensure the functionality of public facilities, particularly in disaster-prone areas. When strategic projects like hospitals, emergency response offices, or evacuation centers are delayed, the resulting negative impacts are not only technical but also social, economic, and humanitarian. A tangible consequence is the erosion of public trust in the government's ability to deliver essential services efficiently. The public tends to directly assess state effectiveness based on the success of infrastructure development. Furthermore, project delays can lead to significant economic losses, such as budget overruns, delayed utilization of facilities, and disruptions to broader social and economic activities (Selim et al., 2015; Zhu et al., 2019). The most critical impact is the disruption of disaster response preparedness. If emergency facilities are unavailable when needed, disaster mitigation and response efforts can be seriously hampered, endangering lives and increasing material losses (Rajesh & Keshav, 2022). Thus, project delays are not merely administrative issues but strategic concerns in building resilient and responsive infrastructure.

According to Presidential Regulation No. 12 of 2021, public procurement is defined as the process of acquiring goods/services required by ministries, agencies, regional work units, and other institutions. This definition encompasses a range of activities aimed at fulfilling government needs for administrative operations and public service delivery (Negi, 2021). In practice, however, public infrastructure development projects often face procurement challenges. One of the recurring issues is tender failure, a condition where the bidding process does not yield a winner or is canceled. A primary cause of tender failure is irrational price offers—either too low (underpriced) or too high (overpriced)—compared to the Owner's Estimate (*Harga Perkiraan Sendiri*/HPS). Such price imbalances may result in bidder disqualification, tender cancellations, and project delays (Budianto et al., 2021).

As stipulated in Presidential Regulation No. 12 of 2021, public procurement involves activities from planning to completion. The regulation states that a skewed unit price is one that exceeds 110% of the unit price listed in the HPS. Such imbalances are frequently considered grounds for tender failure due to concerns over pricing fairness and potential disruption to contract implementation, especially for large-scale projects like multi-story government buildings.

Although a skewed price does not automatically invalidate a bid, discrepancies may prompt further clarification and serve as a note in contract control by the Commitment Making Official/*Pejabat Pembuat Komitmen* (PPK). In practice, procurement committees often face difficulties in evaluating the reasonableness of offers, especially when there is a significant gap between bid values and the HPS. This creates a risk of delayed infrastructure delivery, including critical disaster response facilities that are expected to be available before a disaster occurs(Adistana et al., 2022).

This situation indicates the presence of systemic risks in the government construction procurement process, which often receives limited attention—particularly concerning infrastructure disaster preparedness. Therefore, a structured approach is needed to identify and evaluate potential failures from the outset of procurement. One such approach is Failure Mode and Effect Analysis (FMEA), a risk analysis method used to map potential failure modes.

Failure Mode and Effect Analysis (FMEA) is a widely adopted risk assessment tool in engineering and industrial systems, including manufacturing, aerospace, and construction. In recent years, FMEA has also been effectively applied across several high-risk public sectors. In healthcare, for instance, it has been utilized to assess procurement failures in hospital equipment acquisition and enhance patient safety systems. In the energy sector, FMEA supports the identification of operational risks in power plant procurement and maintenance. Likewise, in the transportation sector, it aids in evaluating the reliability of public transit systems and related infrastructure development. FMEA is a risk assessment method that identifies potential failures in a component or process and prioritizes them based on severity, occurrence, and detection capability (Fan et al., 2020). In construction projects, FMEA can be employed by project managers to detect and eliminate failure possibilities before the execution phase. This approach contributes significantly to minimizing errors in both material procurement and field implementation (Negi, 2021). FMEA's effectiveness has been proven in various sectors, including construction, known for its high complexity and multitude of variables that increase the likelihood of failure (Amelia, 2023; Zhou & Tang, 2018). The method facilitates the identification of failure modes, assessment of their impact and probability, and prioritization based on Risk Priority Number (RPN)—a composite score derived from severity, occurrence, and detection(Wu & Wu, 2021). With this approach, project managers can determine critical areas requiring attention and develop more focused and effective risk mitigation strategies (Rajesh & Keshav, 2022).

Despite the rich body of literature on procurement risks and FMEA applications in technical project management, there is a significant gap in studies that integrate FMEA with tender failure analysis, especially in relation to infrastructure projects supporting disaster resilience. The existing research often treats procurement and disaster preparedness as separate domains. This study addresses this gap by adopting an interdisciplinary approach that applies FMEA to evaluate tender failures caused by pricing deviations and assesses their implications for disaster-related infrastructure readiness.

This research contributes to expanding the methodological application of FMEA by incorporating it into the risk mapping of the procurement phase, offering a structured framework to identify, prioritize, and mitigate tender-related failure modes. It bridges procurement governance with disaster resilience planning—an area increasingly relevant in the face of climate change and increasing natural disaster frequencies.

This study focuses on a government-owned multi-story building project that experienced tender failure, examining how such failure could affect infrastructure preparedness in disaster contexts. The research aims to contribute to a better understanding of the relationship between public procurement processes and disaster risk management systems, while offering recommendations for improving procurement systems to better support disaster-resilient infrastructure development.

Based on the background, the research questions are as follows; (1) what are the potential causes of tender failure in government multi-story building projects due to price deviations from the hps?, (2) how can the failure mode and effect analysis (FMEA) method be used to identify and map key risks in the tender process?, (3) what are the implications of tender failure on the preparedness of public infrastructure for disaster response?

2. Methods

This study adopts a descriptive-qualitative approach supported by quantitative risk assessment using the Failure Mode and Effect Analysis (FMEA) method. The research is designed to identify, evaluate, and prioritize potential failure modes in the public tender process of a multi-story government building project, particularly focusing on failures triggered by price deviations from the Owner's Estimate (HPS).

2.*1 Data collection*

Primary data were obtained through structured interviews and questionnaires distributed to 30 construction professionals, including procurement officers, government project managers, cost estimators, and contractors. Secondary data were collected from official tender documents, procurement regulations (including Presidential Regulation No. 12/2021), technical specifications, bid evaluations, and internal audit reports.

This study employed a two-stage data collection process to gather relevant information necessary for addressing the research objectives. The primary focus was on government tender projects, particularly those under the Ministry of Public Works and Housing (PUPR), conducted between January and August 2021.

In the first stage, in-depth interviews were conducted with experts involved in public procurement, including tender evaluators, government project managers, and construction professionals. These interviews aimed to obtain clarification and verification of the potential risks associated with the tendering process, especially those related to irrational pricing and administrative disqualification.

The second stage involved the distribution of structured questionnaires to professionals with experience in bidding for public construction projects. The purpose of this stage was to identify and assess risk variables using the Failure Mode and Effect Analysis (FMEA) method. The insights gathered from respondents' practical experiences—whether in winning or losing tenders—and their technical knowledge were essential for mapping failure modes and evaluating their priority using the Risk Priority Number (RPN).

This combination of primary and secondary data ensured a comprehensive understanding of the systemic risks in the tender process and provided a strong basis for the FMEA-based analysis.

2.*2 Failure mode and effect analysis (FMEA) procedure*

The FMEA analysis in this study was carried out through a structured sequence of stages. The first stage involved the identification of failure modes within the public tender process, particularly focusing on failure points that could result in bid cancellations due to irrational pricing—either excessively low or high in comparison to the Owner's Estimate (HPS). These failure modes were then evaluated based on three critical dimensions: severity (S), which measures the seriousness of the impact if the failure occurs; occurrence (O), which assesses the likelihood or frequency of the failure; and detection (D), which indicates the system's ability to detect or prevent the failure before its impact is realized. Each dimension was rated on a scale from 1 to 10 by expert respondents, and the Risk Priority Number (RPN) was calculated using the formula :

$$\text{Risk Priority Number (RPN)} = \text{S x O x D} \qquad \text{(Eq 1)}$$

Higher RPN values indicate higher-risk failure modes, which are prioritized for further analysis and mitigation planning. Following the risk assessment, the failure modes with the highest RPN scores were analyzed in terms of their implications for disaster-resilient infrastructure. This step aimed to explore how procurement-related risks could delay the availability of critical infrastructure, such as emergency shelters or public safety buildings, especially in disaster-prone regions. The final step involved data validation through source triangulation. This process compared FMEA results obtained from respondents of diverse backgrounds—procurement practitioners, academic experts, and government project managers. To ensure the systemic risks were interpreted accurately and reliably, the findings were reviewed with construction and disaster management specialists, enhancing the credibility and applicability of the results.

2.3 *Severity scoring criteria in FMEA*

In the application of Failure Mode and Effect Analysis (FMEA), one of the key components is the severity score, which measures the potential impact or seriousness of a failure mode if it occurs. Severity helps project managers and procurement stakeholders to prioritize risks based on the consequences of failure, especially in public infrastructure projects where delay or disqualification can affect critical services such as disaster preparedness.

The scoring system typically uses a scale from 1 (lowest) to 5 (highest), where a higher score indicates a more severe impact. This scale allows for standardized evaluation across various failure modes, thus facilitating risk prioritization through the Risk Priority Number (RPN). The severity levels in this study are adapted from established FMEA literature and contextualized to match the nature of tender failures in Indonesian government construction projects. The FMEA scoring system used in this study involves three key dimensions; severity, occurrence, and detection.

Table 1. Number of receptors in each container

Score	Rating	Qualitative Description
1	Tolerable bad influence	There is a violation of procedures, causing minor consequences, and does not cause the company to be disqualified.
2	Mild severity	A procedural violation occurred; they met the requirements but were not invited to attend the clarification.
3	Moderate severity	There was a procedural violation; a clarification was invited but found things that could not be accounted for so that, according to the project owner, the document was flawed.
4	High severity	There was a procedural violation; the conditions were met, and it was included in the classification, but the clarification and negotiation team was unable to explain in detail the intent of the bid document.
5	Potential severity	A procedural violation occurred; they did not meet the requirements as a tender participant and were disqualified.

(Sugiyanto & Darmawan, 2023)

The Severity Score (Table 1) reflects the seriousness of the impact if a failure mode occurs. The greater the potential negative consequence—such as disqualification, procedural delays, or misinterpretation of tender requirements—the higher the severity rating assigned.

Table 2. Criteria for occurrence score

Score	Rating	Qualitative Description
1	Extremely Improbable	Occurs at least once in 30 tenders
2	Extremely Remote	Occurs at least once in 15 to 29 tenders
3	Remote	Occurs at least once in 7–14 tenders
4	Reasonably Probable	Occurs at least once in 3–6 tenders
5	Frequent	This happens every time participate in a tender

(Velasquez et al., 2021)

The Occurrence Score (Table 2) indicates how frequently a particular failure mode is likely to occur, based on past experiences in the tendering process. A higher occurrence score reflects a more frequent appearance of the issue, thus representing a higher risk. Meanwhile, the Detection Score (Table 3) measures the ability of the system or evaluators to detect or prevent the failure before it results in adverse effects. Lower detection capability leads to a higher detection score, signifying increased risk due to limited preventive control. Together, these three dimensions are used to calculate the Risk Priority Number (RPN), enabling prioritization of risks that require immediate mitigation actions.

Table 3. Criteria for detection score

Score	Qualitative Description
1	Prevention is very effective. No possible causes can arise.
2	Effective prevention. Low probability of occurrence.
3	Possible causes of occurrence are moderate. Prevention methods sometimes still allow the reason to appear.
4	The probability of this happening is still high. Prevention methods are less effective. Cause it keeps coming back.
5	The possibility of this happening is still very high. Prevention methods are not effective. The cause is still recurring.

(Sugiyanto & Darmawan, 2023)

3. Results and Discussion

3.1 Research variables

In this study, the research variables are categorized into two main factors: Tender Document and Estimation. These variables were identified through an in-depth literature review and serve as key contributors to the risk of tender failure in government construction projects. Each factor consists of several variables that reflect specific areas in which failures or inconsistencies frequently occur during the procurement process.

The Tender Document factor includes four variables: specification, basic design, scope of work, and schedule. These components represent the completeness, clarity, and accuracy of the documents provided by the project owner during the bidding stage. Inadequate specifications or unclear project scopes can significantly affect a bidder's ability to submit a rational and competitive proposal.

The Estimation factor is represented by the Human Resources (HR) component, emphasizing the importance of qualified and experienced estimators. Errors in cost estimation often stem from misinterpretation of project requirements, lack of site knowledge, or insufficient pricing data, all of which can lead to irrational bid values and potential disqualification.

Table 4. Research variables and supporting references

Factor	Variable	Explanation	References
Tender Document	1. Specification	Clarity and detail of technical and administrative specifications provided in the tender documents.	(Bargues et al., 2018; Zhou et al., 2021)
	2. Basic Design	Completeness and maturity of the initial design documents submitted during the tendering phase.	(Budianto et al., 2021; Hochstetter et al., 2019)
	3. Scope of Work	Definition and boundary clarity of the tasks, deliverables, and responsibilities in the project.	(Ellis et al., 2021; Kusumarukmi & Adi, 2019)
	4. Schedule	Realism and feasibility of the project timeline as defined by the owner.	(Wimalasena & Gunatilake, 2018; Xia et al., 2017)
Estimation	5. Human Resources (HR)	Competence, skill level, and methodology of the estimators involved in preparing project cost estimations.	(Kamil et al., 2022; Simeone, 2021)

To support the risk identification process and subsequent FMEA analysis, this study established a set of variables derived from existing literature and field observations. The variables are grouped into two main categories: Tender Document and Estimation. Each category includes specific sub-variables and indicators that reflect the root causes of failure modes commonly observed in government building project tenders. These indicators are essential for determining severity, occurrence, and detection scores within the FMEA framework. Table 5 outlines the key variables used in this study, along with their associated indicators. The table 4 below summarizes each variable, its explanation, and the supporting references from previous scholarly work that validate the relevance of these variables in analyzing tender failure risks.

Table 5. Research variables

Variable	Sub Variable	Indicator
Specification	1.1 Unclear specification in tender documents	1.1.1 Limited information regarding required specifications 1.1.2 Lack of experience from specification provider 1.1.3 Lack of detail in the contract documents 1.1.4 Lack of expert personnel due to limited time availability
Basic Design	2.1 Incompatibility with work scope 2.2 Preliminary or incomplete design	2.1.1 Design maturity level is insufficient at tender stage 2.1.2 Delay in design documentation collection 2.1.3 Insufficient time or data for design preparation 2.1.4 Field changes such as unexpected underground conditions
Scope of work	3.1 Scope of work not clearly defined	3.1.1 Scope of work inconsistent with drawings/specifications 3.1.2 Unclear material boundaries in work scope
Schedule	4.1 Unrealistic schedule from Owner	4.1.1 Inaccurate scheduling and lack of Owner's competence
Human Resources (HR)	5.1 Estimation errors	5.1.1 Estimator does not understand the scope of work 5.1.2 Estimator lacks ability to read material/work specs 5.1.3 Estimator fails to analyze unit price per work item 5.1.4 Estimator omits required checklist for estimation
	5.2 Estimates not aligned with actual site	5.2.1 Estimator does not conduct site visit
	5.3 Estimates not competitive	5.3.1 Estimator fails to review required resources 5.3.2 Estimator creates unrealistic schedules during tender
	5.4 Overpriced or underpriced tender value	5.4.1 Inadequate personnel for tender estimation 5.4.2 Very limited time to prepare bids 5.4.3 Failure to gather competitive prices from suppliers/subcontractors 5.4.4 Estimator omits market price fluctuation factors
	5.5 Poor marketing capability	5.5.1 Failure in offering strategy 5.5.2 Failure in negotiation 5.5.3 Failure in prequalification (PQ)

3.2 Respondent characteristics

To support the reliability of the FMEA analysis in this study, a total of 20 respondents were selected through purposive sampling. The selection targeted professionals in the construction sector with direct experience in government procurement and tender processes. The inclusion criteria were: a) A minimum of 5 years of experience in public construction procurement, b) Active roles as Commitment Making Officials (PPK), procurement service unit staff, planning consultants, or technical oversight teams, c) Direct involvement in at least one tender process that experienced failure due to pricing deviations.

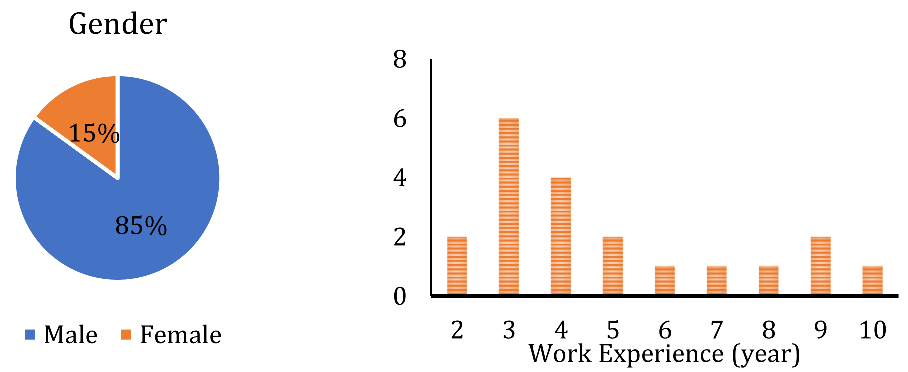

Fig. 1. The characteristics of respondents

The characteristics of these respondents are presented in Figures 1. the gender distribution of respondents is dominated by males, accounting for 85% of the total respondents, while the remaining 15% are female. This reflects the current demographic trend in the construction sector in Indonesia, which remains predominantly male-dominated. Respondents have a range of work experience between 2 to 10 years. The most frequent length of experience is 3 years, with 6 respondents indicating this duration. This suggests that most respondents have sufficient field exposure to provide relevant insights into the risks associated with tender failures.

Before distribution, the questionnaire was validated through expert review involving two senior procurement auditors and one academic researcher in public infrastructure procurement. They assessed the clarity, relevance, and completeness of each item. Feedback from this stage was used to revise ambiguous questions and ensure alignment with the constructs of severity, occurrence, and detection (S-O-D) used in the FMEA method.

3.2 Risk identification and RPN analysis

In this study, questionnaires were used to identify failure incidents and their causes in the tender process through the Failure Mode and Effect Analysis (FMEA) method. The questionnaire included three columns to be filled out by respondents: severity, occurrence, and detection. Respondents were asked to rate the question: “To what extent does each listed variable or failure mode affect the likelihood of losing a tender?” Responses were provided using a Likert scale ranging from 1 to 5, based on specific predefined criteria for each FMEA component.

The values obtained for severity, occurrence, and detection from all respondents were then averaged for each failure mode. The Risk Priority Number (RPN) was calculated by multiplying these three average values. The summarized results are presented in Table 6, which shows the average scores for each indicator, along with their corresponding RPN values. A failure mode is classified as critical if its RPN exceeds or equals the calculated average RPN threshold (critical RPN). This threshold serves as a benchmark to distinguish between non-critical and critical risks.

The purpose of this RPN risk assessment survey is to identify failure modes with the highest potential risk—those with both a high probability of occurrence and severe consequences—while also considering the system's ability (or lack thereof) to detect and mitigate the failure before it causes damage.

Based on the distributed questionnaires, each failure mode was assessed, and the average values of severity, occurrence, and detection were calculated. From these, the individual RPNs were computed. The total RPN value was obtained by averaging all RPN scores, and the critical RPN was derived by calculating the average of the total RPN. This critical threshold was then used to identify and prioritize the most severe indicators requiring mitigation.

The Table 6 above summarizes the failure modes identified in the tender process, along with the corresponding RPN (Risk Priority Number) values. Each sub-variable is assessed using three dimensions—Severity (S), Occurrence (O), and Detection (D)—to calculate its respective RPN. Sub-variables with RPN values above the critical threshold of 20.837 are categorized as critical and require immediate mitigation strategies. These critical points, such as unclear specifications in tender documents, estimation errors, underpricing, and weak marketing capability, highlight areas where risk is most likely to result in tender failure. Conversely, variables marked as non-critical still represent potential risks but with lower urgency for intervention. This prioritization allows stakeholders to focus on mitigating the most impactful risks in the tendering process.

Table 6. Risk prioritization based on FMEA results

Sub Variable		Indicator	Risk Assesment			RPN	Total RPN	Critical RPN	Note
			S	O	D				
1.1	Unclear specification in tender documents	1.1.1	2.5	3.5	2.45	21,438	21,323	20,837	critical
		1.1.2	2.8	3.2	2.3	20,608			
		1.1.3	2.6	3.4	2.4	21,216			
		1.1.4	2.4	3.6	2.55	22,032			
2.1	Incompatibility with work scope	2.1.1	2.5	3.5	2.35	20,563	20,702		non critical
2.2	Preliminary or incomplete design	2.2.1	4	2	2.5	20,000			
		2.2.2	2.65	3.35	2.35	20,862			
		2.2.3	2.7	3.3	2.4	21,384			
3.1	Scope of work not clearly defined	3.1.1	2.55	3.45	2.15	18,915	20,110		non critical
		3.1.2	2.65	3.35	2.4	21,306			
4.1	Unrealistic schedule from Owner	4.1.1	2.75	3.25	2.25	20,109	20,109		non critical
5.1	Estimation errors	5.1.1	3.5	2.5	2.4	21,000	21,938		critical
		5.1.2	3.55	2.45	2.45	21,309			
		5.1.3	3.7	2.3	2.6	22,126			
		5.1.4	3.5	2.5	2.55	22,313			
5.2	Estimates not aligned with actual site	5.2.1	3.45	2.55	2.45	21,554			
5.3	Estimates not competitive	5.3.1	3.2	2.8	2.4	21,504			
		5.3.2	3.5	2.5	2.55	22,313			
5.4	Overpriced or underpriced tender value	5.4.1	3.4	2.6	2.4	21,216			
		5.4.2	2.6	3.4	2.55	22,542			
		5.4.3	3.9	2.1	2.4	19,656			
		5.4.4	3.45	2.55	2.65	23,313			
5.5	Poor marketing capability	5.5.1	3.05	2.95	2.55	22,944			
		5.5.2	2.9	3.1	2.5	22,475			
		5.5.3	3.45	2.55	2.6	22,874			

3.2 Interpretation of high-priority risks

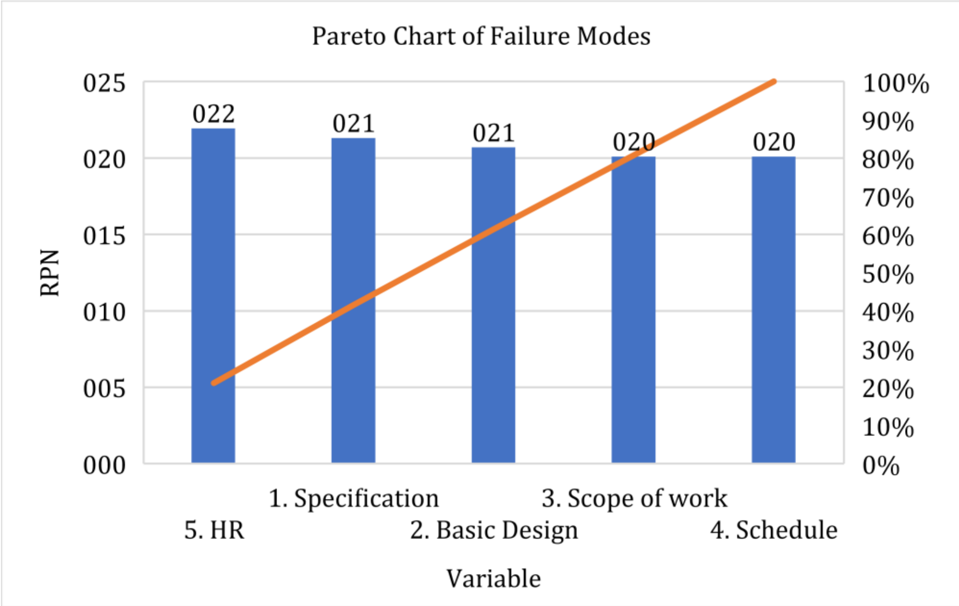

Fig. 2. Pareto chart of failure modes

To enhance the understanding of dominant risk contributors in government construction tender failures, a Pareto Chart (Fig. 2) was constructed using Risk Priority Number (RPN) values obtained from the Failure Mode and Effect Analysis (FMEA). This chart serves as a visual tool to identify the most critical variables in the tendering process, based on the Pareto Principle (commonly referred to as the 80/20 rule), which posits that a small number of causes typically account for the majority of effects. In this study, the Pareto Chart clearly illustrates the cumulative impact of various risk variables on overall project vulnerability and provides a structured framework for prioritizing corrective measures.

The chart reveals five major variables that exceed the defined critical threshold of 20.837: (5) Human Resources (HR), (1) Specification, (2) Basic Design, (3) Scope of Work, and (4) Schedule. Among these, estimation-related risks emerged as the most dominant, with an average RPN of 21.94. This is followed by risks due to unclear specifications (21.32), insufficient basic design (20.70), ambiguous work scope (20.11), and unrealistic scheduling by the owner (20.11). These high values highlight multiple critical vulnerabilities that occur in the early stages of the procurement process.

The findings underscore that weaknesses in estimator competencies, clarity in specification documents, and adequacy in initial design are not merely administrative flaws but systemic problems with far-reaching strategic implications. The high RPN values—resulting from combinations of high severity, high frequency, and low detectability—suggest that these issues require targeted mitigation. Specific corrective actions include training estimators in dynamic pricing and budgeting, early review of tender documents, and improved coordination among design consultants. Implementing these measures can substantially improve the likelihood of successful tenders and reduce delays in public infrastructure delivery.

In addition to variable-level analysis, the study also examined individual indicators to identify the most severe failure modes. The highest RPN value was recorded by Indicator 5.5.3: Failure in Prequalification, with a score of 22.874. This failure is especially critical because it results in immediate disqualification, eliminating the bidder’s opportunity to proceed. Other high-risk indicators include 5.5.1: Failure in Offering Strategy (RPN = 22.944), 5.4.2: Very Limited Time to Prepare Bids (RPN = 22.542), and 5.4.4: Estimator Omits Market Price Fluctuation Factors (RPN = 23.313). These indicators reflect internal weaknesses in bid preparation, particularly concerning pricing strategy, market awareness, and time management.

Ultimately, the analysis suggests that the major vulnerabilities in government tendering are rooted in internal technical deficiencies rather than external market forces. To address these issues, both procurement units and contractors should adopt more structured approaches to bid preparation, allocate sufficient time for procurement activities, and incorporate risk-informed decision-making into project planning. The strategic use of FMEA and Pareto visualization in this context not only serves as a diagnostic tool but also provides a roadmap for reforming public procurement practices toward greater resilience and readiness in emergency infrastructure delivery.

These findings suggest that internal weaknesses—particularly in estimation processes and bid preparation—play a significant role in tender failures. The high severity, frequent occurrence, and limited detection capacity of these risks highlight the urgent need for targeted corrective actions such as improved estimator training, more realistic scheduling, better document management, and strategic marketing capability. Addressing these dominant failure modes can significantly increase a contractor's chances of winning tenders in competitive procurement environments. The results are presented in Table 7 and fig 3.

Table 7. Risk prioritization based on FMEA results

Indicator		Risk Assesment			RPN	Total RPN	Critical RPN
		S	O	D			
1.1.1	Limited information regarding required specifications	2.5	3.5	2.45	21,438		
1.1.2	Lack of experience from specification provider	2.8	3.2	2.3	20,608		
1.1.3	Lack of detail in the contract documents	2.6	3.4	2.4	21,216	21,323	
1.1.4	Lack of expert personnel due to limited time availability	2.4	3.6	2.55	22,032		
5.1.1	Estimator does not understand the scope of work	3.5	2.5	2.4	21,000	21,687	
5.1.2	Estimator lacks ability to read material/work specs	3.55	2.45	2.45	21,309		
5.1.3	Estimator fails to analyze unit price per work item	3.7	2.3	2.6	22,126		
5.1.4	Estimator omits required checklist for estimation	3.5	2.5	2.55	22,313		20,837
5.2.1	Estimator does not conduct site visit	3.45	2.55	2.45	21,554	21,554	
5.3.1	Estimator fails to review required resources	3.2	2.8	2.4	21,504	21,908	
5.3.2	Estimator creates unrealistic schedules during tender	3.5	2.5	2.55	22,313		
5.4.1	Inadequate personnel for tender estimation	3.4	2.6	2.4	21,216	21,682	
5.4.2	Very limited time to prepare bids	2.6	3.4	2.55	22,542		
5.4.3	Failure to gather competitive prices from suppliers/subcontractors	3.9	2.1	2.4	19,656		
5.4.4	Estimator omits market price fluctuation factors	3.45	2.55	2.65	23,313		
5.5.1	Failure in offering strategy	3.05	2.95	2.55	22,944	22,764	
5.5.2	Failure in negotiation	2.9	3.1	2.5	22,475		
5.5.3	Failure in prequalification (PQ)	3.45	2.55	2.6	22,874		

Figure 3 presents a comparative bar chart illustrating the three highest-priority failure modes in the government construction tender process, based on their Risk Priority Number (RPN) and Total RPN. These indicators were derived from a detailed FMEA (Failure Mode and Effects Analysis), focusing on the root causes of tender failures. The chart highlights both individual and aggregated risks associated with specific variables, helping to visualize which failure points most critically affect tender success.

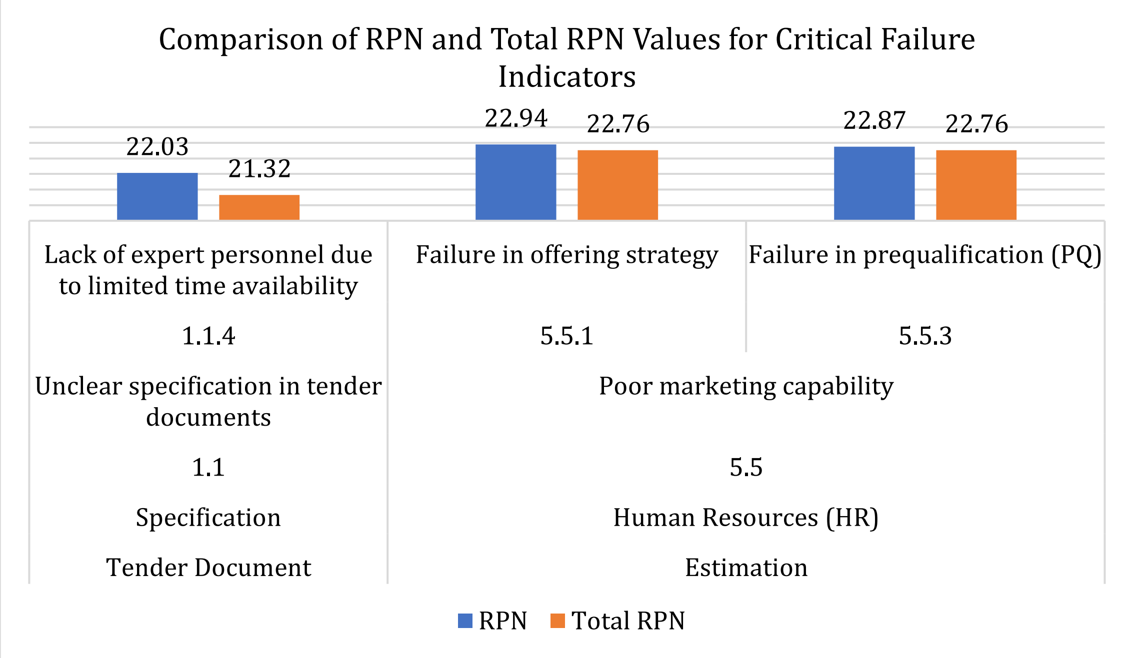

Fig. 3. Comparison of RPN and total RPN values for critical failure indicators

This chart illustrates the comparison between individual Risk Priority Number (RPN) values and the corresponding total RPNs of three critical failure indicators identified in the FMEA analysis: (1) lack of expert personnel due to limited time availability, (2) failure in offering strategy, and (3) failure in prequalification (PQ). The hierarchy of contributing sub-variables is also displayed beneath each indicator. The visual highlights how each failure mode aligns with systemic weaknesses in tender documentation and estimation processes, particularly in terms of time management and marketing capabilities. This comparison reinforces the need for targeted risk mitigation efforts in public procurement practices.

The first significant risk shown is the lack of expert personnel due to limited time availability (Indicator 1.1.4). This risk falls under the sub-variable "Unclear Specification in Tender Documents," which is part of the broader factor "Tender Document." With an individual RPN of 22.03 and a total RPN of 21.32, this issue highlights a common constraint where limited time for bid preparation prevents the allocation of competent experts. As a result, the quality of the technical specifications in tender documents is often compromised, leading to unclear or incomplete information for prospective bidders.

The second major risk is failure in offering strategy (Indicator 5.5.1), which is part of the sub-variable "Poor Marketing Capability" under the "Human Resources (HR)" variable within the Estimation factor. This failure mode has the highest individual RPN of 22.944 and contributes to a total RPN of 22.764. It reflects a strategic weakness in preparing and presenting competitive proposals during tender submission, particularly in aligning technical offers with client expectations and market conditions.

The third highlighted risk is failure in prequalification (PQ) (Indicator 5.5.3), which shares the same sub-variable as the previous risk. With an RPN of 22.874 and the same total RPN of 22.764, this failure is critical because it leads to immediate disqualification of a bidder before their technical or financial proposals are even reviewed. Often, this results from administrative errors, non-compliance with qualification requirements, or inadequate documentation.

Collectively, these three indicators underscore that the most severe vulnerabilities in government tendering processes are rooted in internal weaknesses, particularly those related to human resource readiness, marketing competence, and bid document quality.

The high RPN values across all three suggest that these are not random occurrences but systematic issues requiring targeted corrective action.

3.3 Discussion: Procurement risk as a systemic vulnerability

The findings of this study reaffirm and extend earlier research that highlights procurement-related risks as major contributors to construction project delays. For instance, (Zhou et al., 2021) identified inadequate cost estimation and unclear tender documentation as recurrent factors behind poor tender outcomes. Similarly, (Negi, 2021) emphasized the criticality of internal preparation—especially estimator capability and document clarity—in reducing risk in public procurement processes. Our study complements these findings by quantifying their impact using the Failure Mode and Effect Analysis (FMEA) method and identifying failure in offering strategy, failure in prequalification, and lack of expert personnel as the top three risks based on RPN scoring.

While most prior research focuses on construction execution risks (design flaws, safety, or contractor performance), our study highlights that pre-contract risks—especially in the tendering phase—can cause significant project disruption. In particular, unclear specifications and poor bid strategies are shown to be not just technical oversights but structural vulnerabilities.

The implications of such tender failures on infrastructure delivery during emergencies are significant. Governmental response and recovery efforts are heavily dependent on the timely availability of critical infrastructure—such as hospitals, shelters, and logistical centers. Delays in awarding contracts due to failed tenders directly impact the state's ability to respond to disasters, leaving affected populations vulnerable. As such, procurement must be recognized not just as an administrative function but as a cornerstone of national resilience.

Previous studies align with this assertion. For instance, Awuzie & Monyane, 2020) draw a clear link between procurement inefficiencies and operational bottlenecks in emergency scenarios. They argue that risks such as inadequate prequalification processes and poor bid strategies reflect a capacity deficit within public construction units, which becomes particularly problematic under the pressure of crisis response. Our study reinforces this, demonstrating that internal technical limitations—rather than external market competition—are the primary drivers of tender failure.

To address these vulnerabilities, government institutions should consider several strategic reforms. First, capacity-building programs must be implemented to improve the competence of estimators and marketing personnel, focusing on risk-informed bid preparation. Second, procurement schedules should be restructured to allow sufficient time for internal reviews and validation processes. Third, agencies should invest in real-time market intelligence systems to support accurate and competitive cost estimation.

Furthermore, the adoption of adaptive procurement strategies, could enable more flexible and responsive tendering mechanisms (Zhao et al., 2022). This includes dynamic qualification criteria, modular tender packages, and contingency-based contract clauses that adjust to evolving emergency needs. Such measures can streamline the procurement cycle and enhance government responsiveness during crises.

In summary, this study provides empirical support for the argument that procurement inefficiencies are a systemic vulnerability in public infrastructure development. By addressing these root causes through better training, integration, and policy reform, government institutions can significantly improve their preparedness and resilience in the face of emergencies.

4. Conclusions

This study concludes that tender failure in government multi-story building projects is primarily caused by two interrelated categories: unclear specifications in tender documents and internal estimation weaknesses. Specifically, the lack of expert personnel due to time constraints (RPN 22.03), failure in offering strategies (RPN 22.94), and failure in prequalification (RPN 22.87) were identified as the most critical risks. These findings indicate that tender failure is not merely a technical oversight but reflects deeper systemic vulnerabilities in procurement documentation, estimation capability, and organizational readiness. Using the Failure Mode and Effect Analysis (FMEA) method, the study effectively mapped and ranked these failure modes through Risk Priority Numbers (RPN), enabling the identification of priority areas for risk mitigation. The use of visual tools such as Pareto Charts further strengthened the diagnosis by highlighting the most dominant variables contributing to failure. Beyond the procurement stage, the implications of these failures are significant—particularly during emergencies where infrastructure delivery is time-sensitive. Delays in contract awards for public facilities can hinder critical services, jeopardizing disaster response and recovery. Therefore, improving estimator training, enhancing documentation quality, and adopting adaptive procurement strategies are essential not only for reducing tender risks but also for ensuring resilient and responsive public infrastructure systems.

Theoretically, this study expands the application of Failure Mode and Effect Analysis (FMEA) from its traditional use in industrial engineering to the public procurement domain, demonstrating its robustness in pre-contract risk identification. Practically, the findings offer a scalable framework for government agencies to institutionalize FMEA in procurement workflows, enhancing infrastructure delivery resilience—especially during emergencies. Future research should explore integrating FMEA with real-time procurement monitoring systems and examine its applicability across different infrastructure sectors and administrative contexts to validate its generalizability.

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