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Research Article

Transformation of Risk Mapping in Shopping Mall Construction Through Value Engineering and Risk Assessment (VERA) Approach

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Abstract: The greater the project's level of complexity and constraints, the greater the project risk. This study aims to identify construction risks and determine appropriate responses to address the dominant risks in a shopping mall project. This study interviewed and surveyed construction stakeholders to collect data and analyze it using the Value Engineering and Risk Assessment (VERA) Method. The initial validation for risk factors was analyzed using the Delphi method. This research developed the FAST diagram, and the risk factors were validated using the Delphi method. The study proceeded to the evaluation phase using the FMEA method. Risk assessment was determined using the RPN value; high-risk factors were mitigated to minimize delays in the construction of the shopping mall. The results of the analysis showed three priority risk indicator variables in shopping mall construction: water flooding, low labor productivity, and a lack of professional labor. Based on the VE result, risk mitigation can be categorized into four main functions: risk management capabilities, technical understanding, professional team development, and project risk definition. The VERA method provides clearer targets for performance achievements, which can be achieved by minimizing disasters, improving worker performance, and selecting appropriate technology. The advantage of VERA through proof in case studies is that it makes the right decisions through risk assessment and benefit values such as time and cost aspects of a project activity risk.

Keywords: Building construction; Function Analysis System Technique (FAST) method; Failure Mode and Effects Analysis (FMEA) method; Risk assessment; Value engineering

1. Introduction

Shopping mall development is an indicator of a city's progress and became a post-socialist trend in Europe in the 1990s. In the United States, the culture of shopping in malls has existed since the 1950s (Tamburić et al., 2025; Križan et al., 2021). The peak growth of shopping malls in both regions occurred in the 2000s, but with the development of e-commerce technology and the COVID-19 pandemic, there has been a significant decline, such as in the US, which reached up to 25% or the equivalent of 200 hectares in 2022 (Tereshko and Rudskaya, 2021). This contrasts with the situation in China, where the number of shopping malls continues to grow rapidly, reaching a threefold increase in the number of shopping malls in the United States since 2020. The impact of the new shopping mall development is the trade with global standards, an increase in the new cities in the suburbs, an increase in the area's spatial value, modern social culture, and implications of international policies (Vujisić and Krklješ, 2020). China has successfully continued its shopping mall development by implementing a green mixed-use property development strategy, such as housing, offices, healthcare, and recreational functions (Doan et al., 2021). The growth of shopping malls in Indonesia is relatively low, despite its significant trade potential, with the world's fourth-largest population and domestic consumption reaching 70%. Shopping malls in Indonesia focus on food and beverage sales (17%), clothing

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(69%), electronics (12%), and other (2%), as shown in Figure 1 (Badan Pusat Statistik, 2019). Retail space entrepreneurs must transform and repurpose existing structures to a multi-purpose function to increase the value and sustainability strategies of shopping malls in Indonesia.

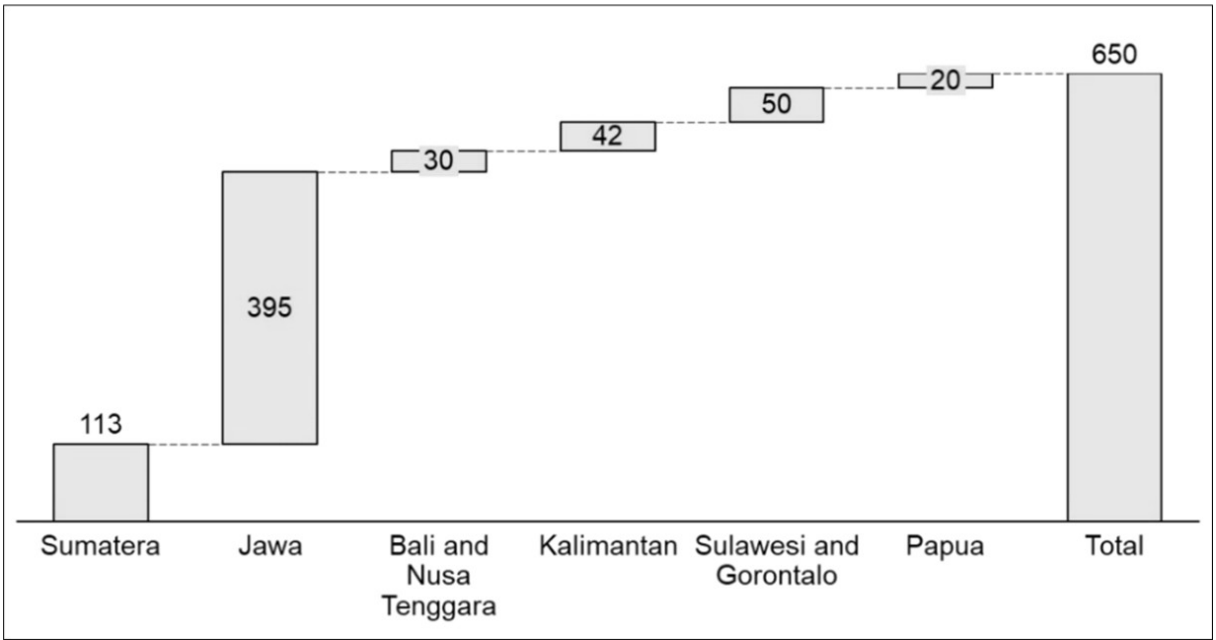


Figure 1 Number of Shopping Malls in Indonesia

The construction market accounts for 14.2% of global GDP, with global growth reaching 5.1% per year (Klave et al., 2025; Deloitte, 2024). The construction industry is one of Indonesia's top four contributors to the country's national gross domestic product. The significant economic growth of 5.43% (greater than global) in the new capital city of Indonesia in East Kalimantan Province is evidence of the construction contribution. The national completed construction value index reflects the physical progress of the completed construction work within three months in an area (Figure 2). The value of completed construction in 2024 grew by 18.71% compared to the same quarter in 2022 (y-on-y). Compared to the previous quarter (Q4 and Q3 2024), the value of completed construction increased by 5.14%. This figure is higher than the q-to-q growth in Q4 and Q3 2022, which only grew by 4.73%.

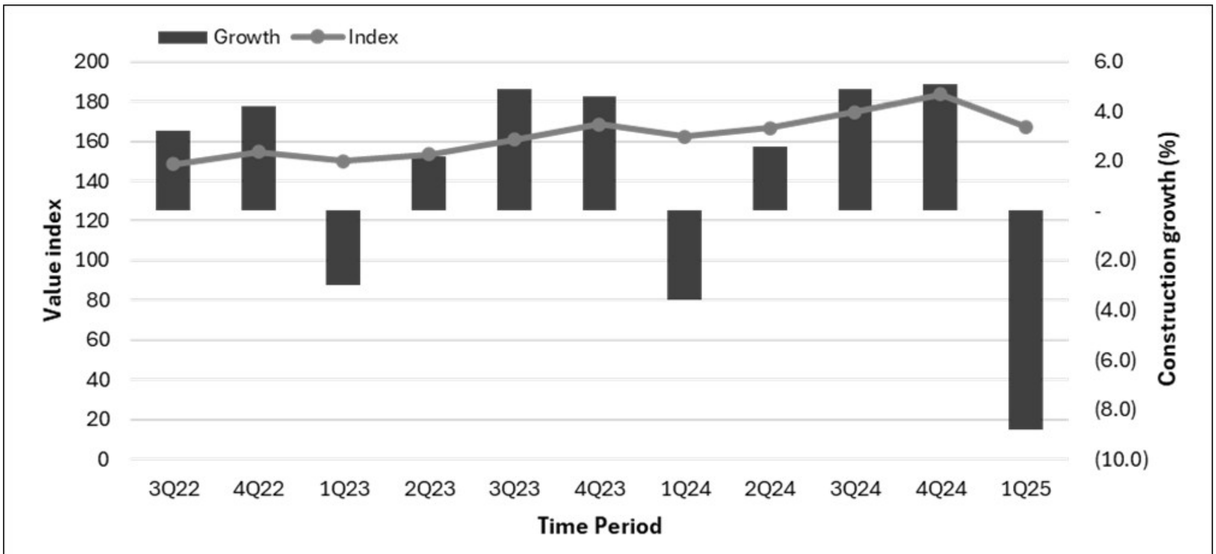


Figure 2 National Construction Growth and Value Index

According to Trigunarsyah, 2004, more than 50% of infrastructure construction and 35% of building construction in Indonesia are classified as heavy engineering construction. Heavy engineering construction involves a complex scope of work and requires heavy handling, beginning with the work stage, construction implementation, and other technical matters. The scope of work complexity and heavy handling cause obstacles or risks in a construction project. Risks in construction projects are generally events that affect project objectives, such as cost, quality, and time. Risks that may occur during construction project implementation include natural disasters, low labor productivity, subcontractor failure, and others. These possible risks can affect the project's quality and quantity (Wibawa, 2021).

Shopping malls are complex structures with a high level of complexity; therefore, a hybrid method is required to accommodate targeted decision-making (Leung et al., 2024). The value added to the creativity phase in the project planning process, innovation, and assessment of the impact of potential risks is simplified and addressed to achieve the project goals. In several previous studies, value engineering and risk assessments have been separately implemented in construction projects. Furthermore, non-complex construction sectors, such as housing construction and manufacturing, in the previous study had relatively similar or repetitive activity characteristics compared to the gradual development of shopping malls, which were applied separately to VE and risk assessment (Table 1).

Table 1 Contributions of the Hybrid VERA Method to the Comprehensive Decision-Making Process

Method	Key Focus in Construction	References
Value Engineering (VE)	Engineering values that truly have function and feasibility at the design or redesign stage so that the system becomes more effective and efficient	Alhumaid et al., 2024; Nejatyan et al., 2023; Othman et al., 2021
Risk Assessment (RA)	Measuring the probability of implementation and large-scale impact of innovation, so that it can be sustainable	Y. Zhu et al., 2025; Leung et al., 2024; Albasyouni, 2021
Hybrid: Value Engineering and Risk Assessment (VERA)	Ideal conditions for creativity and failure mitigation. Furthermore, the decision considered both the challenges and opportunities for innovation	Baihaqi et al., 2023; Meselhy Elsaeed and Gomaa, 2022

Several types of building construction projects exist, such as high-rise buildings, apartments, and shopping malls. Therefore, this study identified the risk factors in the construction implementation and handling of risks that may occur in this shopping mall construction project, which cause additional costs and delays in construction time. Several industries, including aerospace, mechanical, and construction, use risk analysis techniques to determine alternative responses to enhance efficiency. According to Albasyouni, 2021, the risk analysis process using the FMEA method is more accurate for success and competitive advantage than risk management in the Project Management Institute (PMI) version (Jupir et al., 2023). FMEA is specific in identifying not only the impact and severity of the risk but also the detection of the risk that occurred. To provide an overview of decision-making from risk assessment, a model of the relationship between risk and construction performance was developed using value engineering (VE) in the initial stage of this research. using the FAST diagram (Baihaqi et al., 2023). This research provides a transformation in risk assessment in construction projects through the integration of Value Engineering and Risk Assessment (VERA).

2. Methods

This study combines qualitative and quantitative research methods. Qualitative methods using a survey approach with experts for developing a FAST diagram as a VE process and initial validation of the six variables and 50 risk indicators from literature studies. This approach is supported by the decision aiding principle of multiple criteria (Bisdorff et al., 2015). The validation used a structured questionnaire administered by an expert in building construction. The experts answered the questionnaire with agree or disagree choices and provided personal justifications for the variables and indicators obtained from the literature study with a minimum sample size of 10–25 participants (Manyara et al., 2024). The experts assessed the aspects obtained from the literature study and compared them to the implementation in Indonesia. In this step, brainstorming was conducted using insights from experts and then cross-checked in the next round to confirm that all variables and indicators were valid (Okoli and Pawlowski, 2004). After obtaining valid variables, a quantitative study was conducted using a case study for risk assessment, and the FMEA process was used to continue the study. Figure 3 illustrates the holistic framework of these research tools.

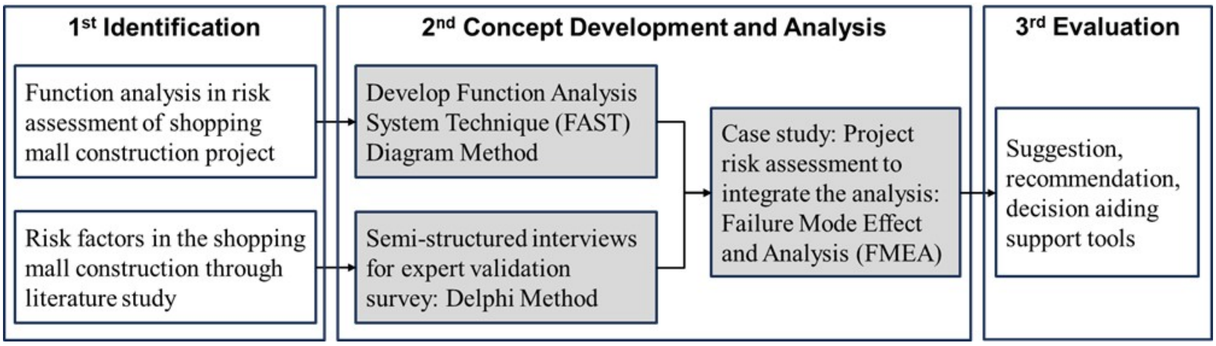


Figure 3 Research framework specifically explaining the concept of VERA development

To test the reliability of the results of the Delphi method regarding the influence of risk indicators on projects in Indonesia in general, this study analyzed the Fleiss Kappa. This analysis method measures the raters' level of agreement when classifying several items into a fixed nominal category (Mishra et al., 2025). The data matrix used in this research is N*k, where N is the total number of items or subjects assessed, and k is the total number of categories used for classification, such as binary classification 0 or 1. In this study, N and k are 50 and 2, respectively. The initial step is to calculate how much agreement there is on each item i against category j, which is the number of pairs of raters who agree divided by the number of all possible pairs of raters:

$$P_i = \frac{1}{n(n-1)} \sum_{j=1}^{k} n_{ij}(n_{ij} - 1) \tag{1}$$

Where P_i is a vector of the agreement proportion for each item. Symbol n represents the total number of raters, and n_{ij} is the number of raters who assigned category j to item i. Now, P_o the average observed proportion of agreement, is calculated as follows:

$$P_o = \frac{1}{N} \sum_{i=1}^{N} P_i \tag{2}$$

When the calculation results have obtained a value P_o, then the value can be known P_e. This value is required to calculate the proportion of agreements expected by chance. For each category j, P_j is calculated by means of

$$P_j = \frac{1}{N \cdot n} \sum_{i=1}^{N} n_{ij} \tag{3}$$

Now, the expected agreement can be calculated. P_e is defined as the sum of the squares of all the average proportions of the categories (P_j). The value of P_e can be calculated using the following approach:

$$P_e = \sum_{j=1}^{k} P_j^2 \tag{4}$$

At the end, you can determine the Fleiss Kappa value (K). The value of K can be determined after obtaining the value P_o and P_e. The K value is an indicator of the level of agreement between raters in assessing item reviews. The K value can be calculated using the following formula:

$$K = \frac{P_o - P_e}{1 - P_e} \tag{5}$$

AK value of >0.75 indicates excellent agreement among the raters. A value of 0.40 <K≤0.75 indicates fair to good agreement, while K≤0.40 indicates poor agreement between the raters (Mishra et al., 2025). The Fleiss Kappa value assumes that each item or indicator is assessed independently and treats all disagreements equally, which, in the case of expert assessment, can be biased, especially when data categories are distributed unbalanced.

FMEA was used in several projects, such as the U.S. Army operation, NASA safety procedures, aerospace, mechanical, and construction sectors. The risk was assessed using the FMEA method (Moreira et al., 2021). FMEA has an advantage in risk analysis and is a common method in the construction sector. Furthermore, FMEA not only identifies but also provides recommendations for risk management (Lo and Liou, 2018). Some of the previous research was a risk analysis topic that was limited to safety procedures and had no specific focus on a commercial shopping mall. FMEA provides more details than other methods in assessing the potential risk, such as importance and significance. The risk priority number (RPN) is the total of the risk priority. This makes it easy to reduce risks because all risk categories are ranked based on the impact, occurrence, and detection of observation objects (Albasyouni, 2021).

Value engineering is an effort to increase a product or service's value or cost efficiency, or a combination of both, without changing the expected quality (Berawi et al., 2023). The assessment process is further refined with a combination of methods, particularly in decision-making (Baihaqi et al., 2023). The VE method is implemented in three stages: identifying the scope of the review (pre-study), developing a VE solution (workshop), and evaluating (post-workshop) to ensure the best model implementation (Dahooie et al., 2020). Figure 3 shows the details of the six VE processes: information, analysis, creativity, evaluation, development, and presentation (Ginting et al., 2025).

Each study has a relationship between variables that is formed based on a literature study and then tests the relationship of influence between variables. This study confirmed the correlation level between the independent and dependent variables, as shown in Table 2 (Asmone et al., 2023; Green, 2020). Some references in the literature study showed the variables and indicators to build this research theory, followed by an expert survey validation process. The validation results are continued with a survey through data collection from stakeholders related to the hotel development project. The FMEA method was used to analyze the survey results from the topics discussed in this study.

Based on the review of Figure 3, variable X (X1, X2, X3, X4, X5, and X6) is the independent variable, while variable Y is the dependent variable, meaning that variable X affects variable Y. The independent variables (X) obtained are the force majeure factor, construction management factor, internal technical factor, internal non-technical factor, human resource factor, and construction implementation factor. The dependent variable (Y) is the additional cost and delay of the performance of the construction project. Variable X is the independent variable, followed by several indicators. Risk criteria or variables were assessed further as a risk in shopping mall construction by the expert using a numerical assessment.

Table 2 Influential risk factors on the performance of construction projects

Dimensions	Code	Risk Factor	References
X1. Force Majeure	X1.1	Earthquake	Klave et al. (2025)
	X1.2	Fire	Brukhovetska (2023)
	X1.3	Unpredictable Weather	
	X1.4	Flood	
	X1.5	War	
X2. Construction Management	X2.1	Lack of Work Control	Mir and Pinnington, 2014
	X2.2	Inexperienced Staff	Kerzner, 2023
	X2.3	Lack of Precise Planning	Suleiman, 2021
	X2.4	Complexity of Regulation	Rahman et al., 2013
	X2.5	Low Level of Employee Discipline	Edition, 2018
	X2.6	Poor Project Supervision	Hatefi and Tamošaitienė, 2019
	X2.7	Miscoordination in Management	Yousri et al., 2023
	X2.8	Incomplete Regulatory Reports	
	X2.9	Conflict Between Project Stakeholder	
X3. Internal Technical	X3a.1	Quantity and Quality of Iron Do not Match Technical Specifications	Tanko et al., 2018 Edition, 2018
	X3a.2	Quantity and Quality of Concrete do not Match Technical Specifications	Wang et al., 2025; Hatefi and Tamošaitienė, 2019
	X3a.3	Errors in Assembling Reinforcement	F. Zhu et al., 2022
	X3a.4	Marking Errors	El-Karim et al., 2017
	X3a.5	Poor Reinforcement Connections	Hatefi and Tamošaitienė, 2019
	X3a.6	Errors in Assembling Formwork	
	X3a.7	Inappropriate Formwork Selection	
	X3a.8	Location Cast not Clean	
	X3a.9	Concrete Pouring Error	
	X3a.10	Incorrect Formwork Removal Time	
	X3a.11	Accuracy of Material Use	
	X3b.1	Loss of Material	
	X3b.2	Volume of Material Sent is not Correct	
	X3b.3	Lack of Material Storage Space	
	X3b.4	Material Quality does not Match	
	X3b.5	Delay in Material Delivery	
	X3c.1	Low Equipment Productivity	
	X3c.2	Delay in Equipment Arrival	
	X3c.3	Equipment Damage	
	X3c.4	Lack of Operator Experience	
X4. Internal non-technical	X4.1	Weak Cost Control System	Dahooie et al., 2020; Kissi et al., 2017; Eschenbach and Lewis, 2016
	X4.2	Delayed Owner Payments	
	X4.3	Additional Work	
	X4.4	Influence of National Economic Policy	
X5. Human Resources	X5.1	Low Labor Productivity	Alhumaid et al., 2024
	X5.2	Lack of Professional Staff	Temitope et al., 2023
	X5.3	Lack of Workers Number	Cheng and Darsa, 2021
	X5.4	Work Accidents	
	X5.5	Labor Strikes	
X6. Execution Process	X6.1	Difficulties in Using New Technology	Nejatyan et al., 2023; Anbari, 2003
	X6.2	Design Changes	
	X6.3	Difficulty of Access to Reach the Site	Setiawan and Riantini, 2021
	X6.4	Staff Errors in Reading Drawings	Kamyab and Alamatian, 2017
	X6.5	Work not on Schedule	
	X6.6	Damage and Sabotage to the Project	
	X6.7	Security Disturbances at the Project	

Primary data were collected through brainstorming with experts and analyzed based on the methods used in this study. The dominant risk factors have been the input for the risk mitigation process by using the FMEA. The FMEA method is used to assess project risk. The final source of the project risk was the qualitative analysis results. The dominant risks are assessed based on project constraints, such as project costs and time, especially in the XYZ shopping mall project case study. This method used the RPN value in the data analysis. The RPN value determines the level of risk of the variables toward project performance. It is a crucial element in the FMEA method because it provides an understanding of risk priorities, including the identification of dominant risks (Sari, 2016). Here is the formula for RPN:

$$RPN = Severity \times Occurrence \times Detection \tag{6}$$

According to Equation 1, the RPN measures the risk by considering the impact and significance of the project activity. Using this technique, FMEA will forecast the risk priority to the risk owner (Rahmatin et al., 2018). Table 3 details the risk criteria and the definition of this research. Building construction risks were determined by considering previous research and expert judgment with a case study in Indonesia. Furthermore, the expert was tasked with conducting brainstorming in the risk assessment process. The expert must have a bachelor's degree in civil engineering, a minimum of 10 years of experience in building construction projects, and experience in a project leader position. Experts assessed the risk of the project performance indicators based on severity, occurrence, and detection criteria on a 1-10 scale (Albasyouni, 2021). This research takes data from the XYZ Shopping Mall in Bekasi City, Indonesia, as a case study, where the developer is one of the five largest shopping mall areas in Indonesia.

Severity is the first step in risk analysis by calculating how much an event's impact or intensity affects the process output. This impact is ranked on a scale from 1 to 10, where 10 is the worst impact. Occurrence is the possibility of a cause that will occur and result in failure or risk during a system process. The scale for this occurrence criterion ranges from 1 to 10. The number 10 represents the number of risks that always occur. Detection is indicated by a value or a scale from 1 to 10. This value can be seen from the current control. Therefore, detection is a measurement of the ability to control failure or can be called a detector. The RPN value or priority risk number is obtained from Equation 1 (Situngkir, 2019). Finally, this total RPN value could be defined as ranging from 1 (absolute best) to 1000 (worst risk), as shown in Table 4.

The experts used in the initial stage of the final validation of the research variables were company leaders. They had experience in developing shopping malls, primarily as project managers and technical engineers. Data collection through a brainstorming process with experts or specialists determined the value of risk indicators to fill the data required by the FMEA method. This involved in-depth discussions in the meeting room and structured questions as a guide for filling in the RPN numbers. The experts who underwent the brainstorming process were formed into a team called the expert team. This team consisted of experts familiar with the entire scope of the project, such as the company's Project Manager (PM) and Site Manager (SM). They were tasked not only with being the final validators but also with providing mitigation measures in the event of a project risk.

The case study used XYZ Shopping Mall, one of the largest shopping malls in Indonesia. The land area of the XYZ Shopping Mall is 23 hectares, with a building area of 160,000 sum. It has four floors and one basement. The developer of XYZ Shopping develops in 2 stages. The construction team completed the first phase in 2013 for US$ 48.5 million. Subsequently, the developer spent more than US$ 60.6 million on construction costs to complete the second phase in 2025. This research used the project as a case study in the second phase of the construction process. However, this research involves the same stakeholders in the construction of phases 1 and 2. The risks associated with shopping mall construction are more easily and specifically identified by these stakeholders.

Table 3 Details of RPN criteria based on the ranking value

Rank	Severity		Occurrence		Detection	
	Impact	Criteria	Event	Probability	Effect	Criteria
1	No	No impact and no adjustment	Almost never	0–1	Almost certain	Detected
2	Very low	Testing continues, with low trouble	Remote	>1–2	Very high	Very easy to detect
3	Low	Regular testing and performance degradation	The least	>2–3	High	Easy to detect
4	Minor	Testing conducted revealed significant performance degradation	Few	>3–4	Moderately high	Detected
5	Moderate	Testing not normal, with/without defects	Low	>4–5	Moderately high	Quite easy to detect
6	Significant	Cannot be tested because of light defect to the system	Medium	>5–6	Low	Relatively rare detection
7	Major	Cannot be tested, and the defect system is hard	A bit high	>6–7	Very low	Very rarely detected
8	Extreme	Cannot be tested, very hard defect system	High	>7–8	Remote	Relatively difficult to detect
9	Serious	Failed testing, defect system with warning	Very high	>8–9	Very remote	Hard to detect
10	Dangerous	Failed testing, defect system without warning	Almost ever	>9	Not sure	Cannot be detected

Table 4 Risk priority number category and treatment

Risk Priority Number	Category	Treatment
192–1000	High	Make repairs now
65–191	Medium	Efforts to improve
0–64	Low	Negligible risk

3. Results and Discussion

3.1 Identification Phase

The identification stage is a way to understand the functional details of a product or service, gaining insights to optimize the value generated at the most efficient cost. Table 5 presents the results of identifying the risk assessment service objectives, specifically mitigating unexpected events that impact project performance, particularly in shopping mall development. Risk mitigation has the advantage of improving project performance by anticipating critical disruptions in shopping mall construction projects that can impact costs, delay the construction schedule, and lower quality standards. Then, several experts provided input regarding the results of the additional function assessment for each main function of the risk assessment service process, including avoiding disasters and always achieving high project performance. Functions that can be completed in a single assessment process include the ability to obtain the right technology to perform the work. Risk mitigation must be implemented through risk management: understanding the effective project implementation methods, building a professional team, and defining project risks. The experts who provided input for this risk assessment model are experienced construction industry professionals, specifically those involved in shopping mall development. The results of this identification will establish a value engineering model in risk mitigation, specifically, risks that have a critical impact.

Table 5 Identified Integrated Risk Assessment Function Concept

Base function	Risks mitigation
Design objectives	Cost-efficient; Project on schedule; Quality standard
All time functions	Avoid the impact of disasters, have high employee performance
At one-time function	Using appropriate technology
Supporting functions	Achieved project performance through good risk management: 1. Manage project risks: make proper planning and intensively monitor the project 2. Understand the work method: learn the SOP and identify the regulation 3. Create a project team: hiring a professional and building capacity 4. Define project risks: collect data and analyze risks

The decision-making process on a project used the VERA method for risk recognition and assessment, which provides more comprehensive results. This method's initial stage outlines the basic function of concept integration or risk mitigation, impacts efficient project financing, timely project scheduling, and meeting quality standards according to established standards. According to the results of discussions with experts, the risk mitigation model outlines two aspects: understanding the potential impact of disasters and achieving high employee performance in a shopping mall project. The use of appropriate technology is a holistic approach to initial risk mitigation. Figure 4 shows the complete VE results obtained using the FAST diagram technique.

3.2 Concept development and analysis phase

This study chose 11 experts to validate the risk factors affecting the performance of shopping mall construction. There are several positions: three project managers, one site manager, two structural engineers, and five engineering academics who know the building project. All of them have more than 10 years of experience in building construction. Likewise, academic experts are lecturers at the campus owned by one of the largest shopping mall developers in Indonesia. The expert profile details are shown in Table 6.

The Fleiss Kappa value calculation shows that the validation results can be tested reliably. Data were collected from 11 experts who assessed the relationship between risk types identified in the literature and a shopping mall construction project in Indonesia. In the Delphi assessment, the number of experts was not the determining factor in the success of the results, but rather their quality. However, this study not only determines the quality experts but also attempts to meet the minimum sample size in the Delhi method, namely, between 10 and 20 experts involved (Manyara et al., 2024; Nejatyan et al., 2023). Before this study proceeded to analyze the Delphi survey results, a validity and reliability test was conducted. This reliability test used Fleiss Kappa analysis because this study collected binary data, and the variables' indicators or items were the results of previous research that had been tested for validity but needed to be retested for reliability based on conditions in Indonesia. Fleiss Kappa is an appropriate analysis method because it can provide results regarding the level of agreement among experts in assessing or ranking the reviewed aspects (Table 7).

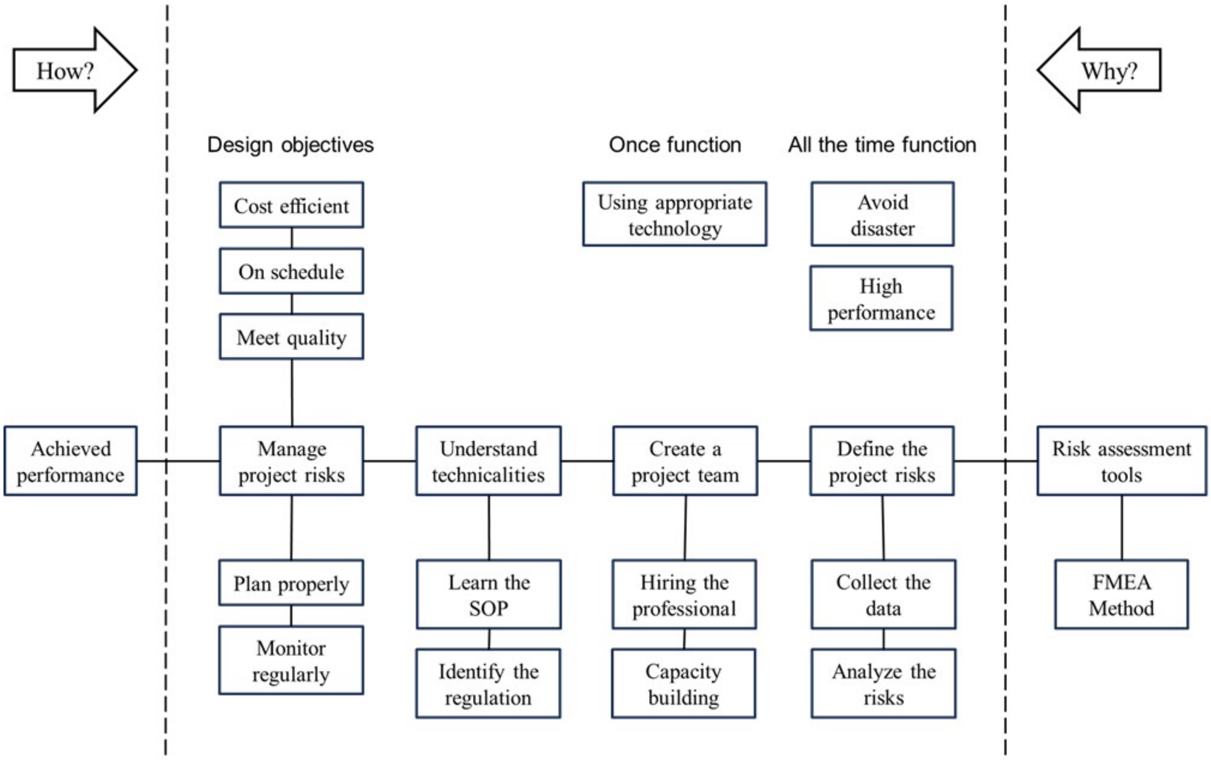


Figure 4 Function Analysis System Technique (FAST) Diagram of Risk Mitigation Process

Table 6 Experts' Profile List for the Indicator Validation Process

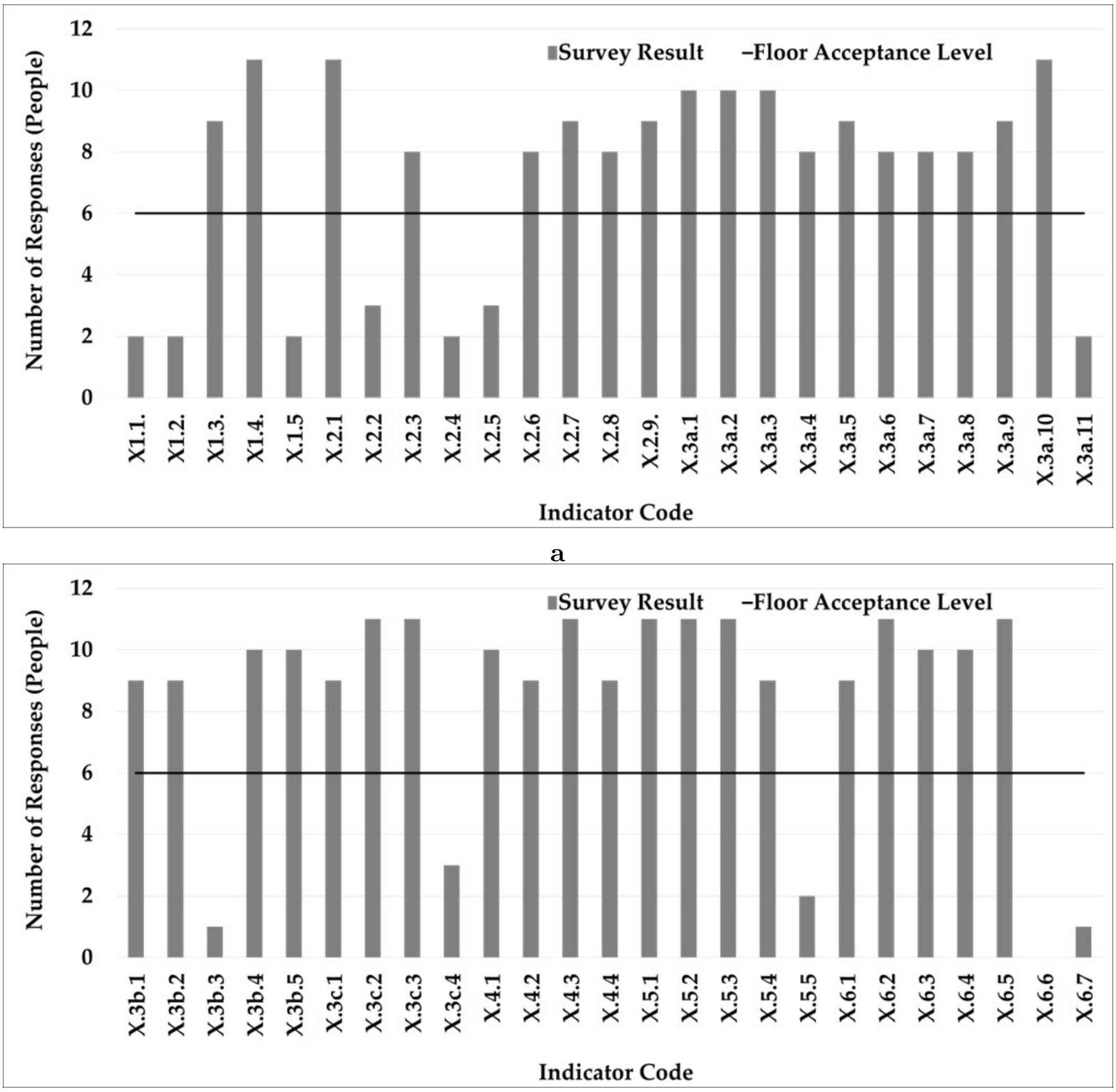
Expert	Education	Experience	Job's Position	Occupation Sector
1.	Bachelor	21–30	Project Manager	General Contractor
2.	Bachelor	11–20	Site Manager	General Contractor
3.	Bachelor	11–20	Engineer	General Contractor
4.	Bachelor	21–30	Project Manager	General Contractor
5.	Bachelor	11–20	Engineer	General Contractor
6.	Master	11–20	Project Manager	Developer
7.	Doctor	11–20	Lecturer in Civil Engineering	Academia
8.	Master	11–20	Lecturer in Architecture	Academia
9.	Master	11–20	Lecturer in Civil Engineering	Academia
10.	Doctor	11–20	Lecturer in Civil Engineering	Academia
11.	Master	11–20	Lecturer in Civil Engineering	Academia

The next step is to calculate the proportion of observed agreements, P_0 value was 0.76. Then, this study calculates the expected proportion of agreement, appropriate value p_1 was 0.71 and inappropriate p_0 was 0.29. The results produce the sum of the squares of the average proportion. P_e was 0.58, so the Kappa Fleiss value (K) was 0.42. The Fleiss Kappa value shows 0.40 <K≤0.75 indicating fair to good agreement. This condition indicates that observations can be continued with variable indicators whose reliability has been tested (Mishra et al., 2025).

Table 7 Agreement between Indonesian construction experts in building projects

Risk Code	n_{i1} (Yes)	n_{i0} (No)	$n_{i1}(n_{i1}-1)$	$n_{i0}(n_{i0}-1)$	$\sum n_{ij}(n_{ij}-1)$	P_j
X1.1	2	9	2	72	74	0.67
X1.2	2	9	2	72	74	0.67
X1.3	9	2	72	2	74	0.67
X1.4	11	0	110	0	110	1.00
X1.5	2	9	2	72	74	0.67
X2.1	11	0	110	0	110	1.00
X2.2	3	8	6	56	62	0.56
X2.3	8	3	56	6	62	0.56
X2.4	2	9	2	72	74	0.67
X2.5	3	8	6	56	62	0.56
X2.6	8	3	56	6	62	0.56
X2.7	9	2	72	2	74	0.67
X2.8	8	3	56	6	62	0.56
X2.9	9	2	72	2	74	0.67
X3a.1	10	1	90	0	90	0.82
X3a.2	10	1	90	0	90	0.82
X3a.3	10	1	90	0	90	0.82
X3a.4	8	3	56	6	62	0.56
X3a.5	9	2	72	2	74	0.67
X3a.6	8	3	56	6	62	0.56
X3a.7	8	3	56	6	62	0.56
X3a.8	8	3	56	6	62	0.56
X3a.9	9	2	72	2	74	0.67
X3a.10	11	0	110	0	110	1.00
X3a.11	2	9	2	72	74	0.67
X3b.1	9	2	72	2	74	0.67
X3b.2	9	2	72	2	74	0.67
X3b.3	1	10	0	90	90	0.82
X3b.4	10	1	90	0	90	0.82
X3b.5	10	1	90	0	90	0.82
X3c.1	9	2	72	2	74	0.67
X3c.2	11	0	110	0	110	1.00
X3c.3	11	0	110	0	110	1.00
X3c.4	3	8	6	56	62	0.56
X4.1	10	1	90	0	90	0.82
X4.2	9	2	72	2	74	0.67
X4.3	11	0	110	0	110	1.00
X4.4	9	2	72	2	74	0.67
X5.1	11	0	110	0	110	1.00
X5.2	11	0	110	0	110	1.00
X5.3	11	0	110	0	110	1.00
X5.4	9	2	72	2	74	0.67
X5.5	2	9	2	72	74	0.67
X6.1	9	2	72	2	74	0.67
X6.2	11	0	110	0	110	1.00
X6.3	10	1	90	0	90	0.82
X6.4	10	1	90	0	90	0.82
X6.5	11	0	110	0	110	1.00
X6.6	0	11	0	110	110	1.00
X6.7	1	10	0	90	90	0.82
Total	388	162				37.93

Before this research went to the next step, the experts selected the related risk factors in shopping mall construction using the FMEA method. Expert validation was conducted in two rounds to further focus on the risk factors that were very influential in the reviewed project. The stages of the expert validation rounds conducted in this study are as follows. The first round of the survey assessed several variables obtained from the literature and field observations (Figure 5). Based on this survey, 12 of the 50 indicators were eliminated.



b

Figure 5 Expert Response in the Risk Indicators Validation Process

Expert validation was conducted through a survey method using a structured questionnaire. In the second round, the experts reviewed the results of the Delphi analysis from the first round of surveys and provided feedback on these factors. In the second round, the experts identified four additional indicators: inaccurate work sequence planning, incomplete initial project data resulting in misinterpretation in project implementation in the field, lack of accuracy in formwork calculations, and incompatibility of technology with field conditions. After the second round of the validation process, three new indicators were selected: inaccurate work sequence planning (add as an indicator in variable X2), incomplete initial project data resulting in misinterpretation in project implementation in the field (add as an indicator in variable X2), and incompatibility of technology with field conditions (add as an indicator in variable X6). In the first phase of expert validation, 38 risk indicators of variables were identified that would be used in the next phase.

The first step in the FMEA method is to gather five practitioners' experts (number 1-5 in Table 6) in one place to determine the severity, occurrence, and detection values. These values consider the case study of the XYZ Shopping Mall development. This brainstorming strengthens this study's analysis because the experts can exchange ideas regarding risk assessment and management. Table 8 presents the results of the RPN assessment. There are three (7.9%) risk indicators in the high-risk priority category. The other risk indicators are classified as medium and low, consisting of nine (23.7%) and twenty-six (68.4%) risk indicators, respectively.

Table 8 Measurement results of shopping mall construction risk

Code	S	O	D	RPN	Rank	Category	Code	S	O	D	RPN	Rank	Category
X1.3	3	3	3	27	18	Low	X3b.2	3	3	1	9	21	Low
X1.4	7	6	8	336	1	**High**	X3b.4	5	3	5	75	8	Medium
X2.1	5	5	2	50	12	Low	X3b.5	3	3	2	18	19	Low
X2.3	5	3	2	30	16	Low	X3c.1	3	6	3	54	11	Low
X2.6	5	3	2	30	16	Low	X3c.2	3	3	2	18	19	Low
X2.7	5	5	6	150	5	Medium	X3c.3	3	6	2	36	15	Low
X2.8	5	3	7	105	6	Medium	X4.1	2	3	3	18	19	Low
X2.9	5	3	2	30	16	Low	X4.2	2	2	2	8	22	Low
X3a.1	5	3	7	105	6	Medium	X4.3	6	7	2	84	7	Medium
X3a.2	5	3	3	45	13	Low	X4.4	2	2	7	28	17	Low
X3a.3	4	3	3	36	15	Low	X5.1	6	7	5	210	2	**High**
X3a.4	4	3	3	36	15	Low	X5.2	8	6	4	192	3	**High**
X3a.5	4	3	3	36	15	Low	X5.3	4	7	3	84	7	Medium
X3a.6	2	3	5	30	16	Low	X5.4	2	2	2	8	22	Low
X3a.7	5	3	2	30	16	Low	X6.1	3	2	5	30	16	Low
X3a.8	2	3	5	30	16	Low	X6.2	6	7	2	84	7	Medium
X3a.9	4	3	3	36	15	Low	X6.3	7	1	2	14	20	Low
X3a.10	2	3	5	30	16	Low	X6.4	5	2	5	50	12	Low
X3b.1	5	3	7	105	6	Medium	X6.5	6	4	3	72	9	Medium

Based on the results of the risk assessment by experts on the shopping mall construction they are working on, three major risks are flooding (X.1.4), low labor productivity (X.5.1), and lack of professional staff (X.5.2). These three indicators are derived from two aspects of the construction risk review, namely, Force Majeure (X1) and Human Resources (X5). Based on the results of expert discussions, this risk assessment is meaningful in keeping project performance on track, such as project implementation time and costs. Therefore, an understanding of these risks needs to be understood by all risk owners, which can be divided into three parts according to the RPN category, namely, for the high category handled by the company's top management, medium and low categories are each mitigated by the Messo Level or managers and supervisors, and the field technical team.

According to Moreira et al., 2021, RPN calculation is important, but there are additional procedures and visual analysis to identify further failure modes. The FMEA process also needs to consider potential that would otherwise have remained undetected in the RPN calculation procedure. Figure 6 shows three high priorities based on RPN calculation, and three more were added due to their high priority of severity and occurrence. The risk management calculation model that considers severity and occurrence is an assessment system from the PMI (Albasyouni, 2021). Three additional high-priority risk factors, namely, internal non-technical (X4) and execution process (X6), were added.

The six most important failure modes were analyzed by the research and project teams to determine which had the most important value to the project construction process.s. According to Albasyouni, 2021, there is a need for new, more innovative methods for analyzing the potential risks in constructionk. FMEA is a simple, efficient, and straightforward analysis process capable of displaying comprehensive risk mapping. Furthermore, an assessment of the EISCO management approach (PMI), RPN for FMEA, and fuzzy RPN showed that the PMI and RPN rankings appeared closer when compared to fuzzy RPN, thus recommending the development of RPN with FMEA. Furthermore, Baihaqi et al., 2023 demonstrated that value engineering analysis can present cause-and-effect relationships and weighting results comparing approacheses. Therefore, VERA is more reliable than Fuzzy DEMATEL-AHP due to evidence of more targeted risk management, especially in achieving time and cost performance in a construction project.

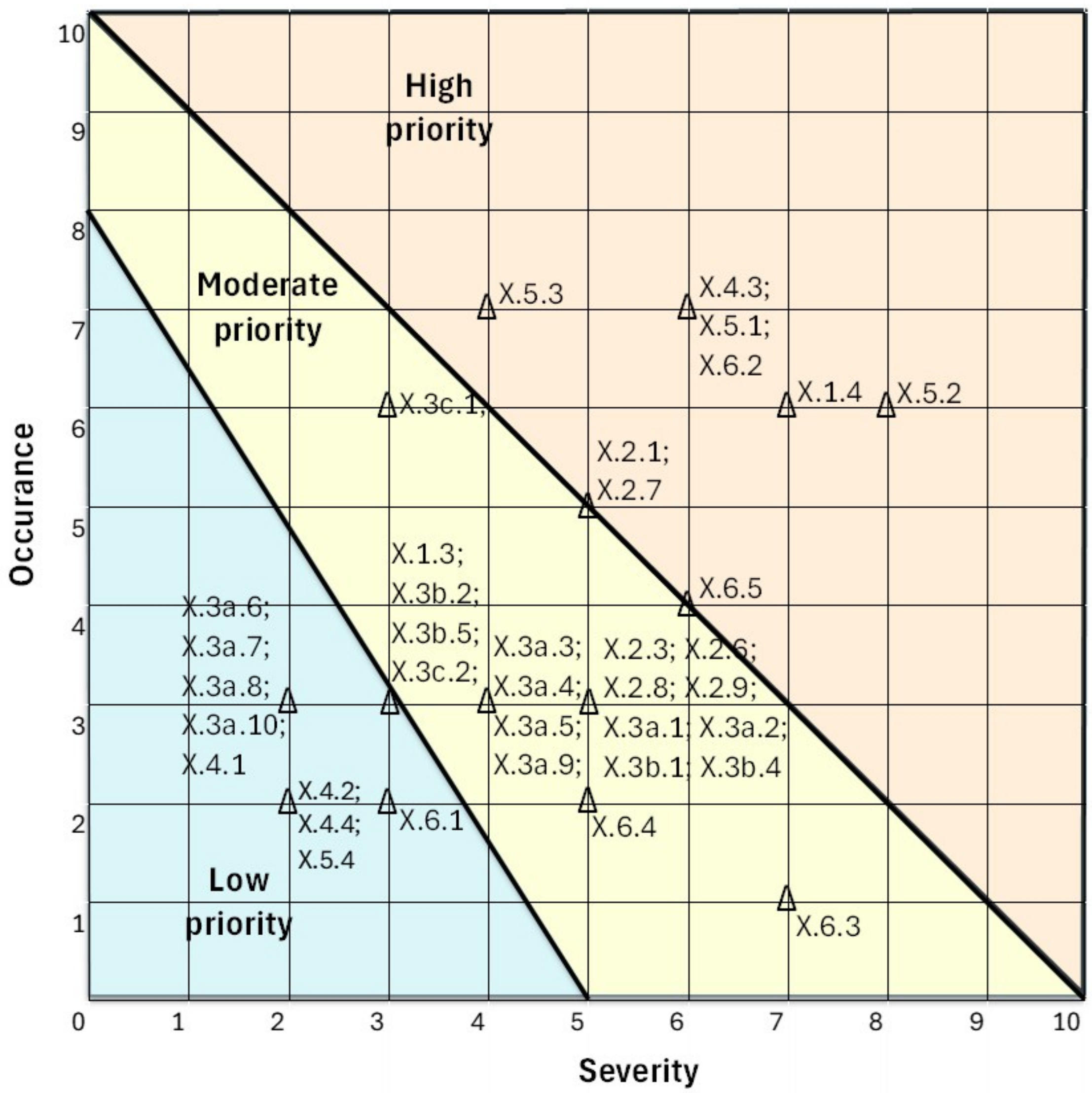


Figure 6 Prioritization analysis of failure severity and occurrence

3.3 Evaluation Phase

Several previous studies have shown that there are relatively few alternative risk assessment methods outside the PMI guidance approach. Previous research in India has shown that FMEA is a superior method to the PMI approach due to its ability to categorize risks based on their risk ranking (Lo and Liou, 2018). This makes FMEA superior and easier to implement, especially for risk mitigation follow-up (Albasyouni, 2021). Furthermore, relatively little research has assessed risks in construction projects, such as manufacturing, building construction, and metro rail projects (Sarkar and Singh, 2022). Therefore, this study of shopping mall construction performance risks using the FMEA method is the first after the VE process and can enrich risk assessments across various construction types.

Based on several types of construction in the reference, the construction risks priority generally includes company cash flow issues, contractor inexperience, late payments by the building owner, unreliable cost planning, changes in raw material prices, and design errors (Albasyouni, 2021). Compared to the risks encountered in the construction of shopping malls, the company's cash flow and late payments from the owner are not a risk priority. This indicates that the owner's ability to fund the project and select contractors with strong cash flow has been thoroughly tested. The risk priority in a shopping mall construction project is force majeure in handling weather forecasting, especially hard rain, which causes flooding during the substructure work process, and the project staff's relatively low project labor capability and professionalism.

The shopping mall project in which this research case study occurred experienced a decline in progress due to project delays. This decline occurred during the pile foundation work activity. Pile driving is performed using a heavy equipment called a hydraulic static pile driver (HSPD). Mobilization takes a long time, but it has good penetration capabilities and is more accurate than other methods. Based on the research of Syahrudin et al., 2022, HSPD is a method for inserting deep foundations into the ground that falls into the driven pile classification. The HSPD inserts piles into the ground using hydraulic pressure, using the dead load from the HSPD machine or a counterweight system. Table 9 (in supplementary file) shows the advantages and disadvantages of various driven piles.

In the initial stages of selecting the foundation piling method, the project chose hammer piles because they were considered to be faster. However, the building density around the construction site indicated quite dense conditions, and the rain fell every day according to the Meteorology, Climatology, and Geophysics Agency predictions. Mitigation efforts for flood risk factors discussed with experts included building perimeter gutters to channel water to sump pits, which would later be pumped and channeled to city channels, increasing the effectiveness of flood management by increasing the number of pumps and creating sump pits according to the flooding cause, and implementing deep dewatering in the upper structure work process using the semi-dewatering concept. Therefore, replacing the pile driving work method with HSPD could shorten the work time, although it did increase costs. One of the advantages of HSPD is that it is not dependent on weather because it can determine the carrying capacity using hydraulic working capacity.

High rainfall and groundwater levels were one of the obstacles that caused delays in pile-driving work in the basement. It caused flooding. Pile driving was conducted from September 2023 to April 2024, while the initial pile driving contract was supposed to have been completed on January 31, 2024. The highest rainfall in Indonesia occurred from January to February, which includes the eight months of pile driving activity. Initially, the hammer pile driving method was selected, indicating that the project team could complete the piling in 240 days with a tool productivity of 19 piles per day for one hammer pile under these weather conditions. However, the calculation results of changing the work method to HSPD due to the risk of environmental disturbances and flooding showed that the work could be completed on time (135 days), with a tool productivity of 34 piles per day. The foundation cost reaches 10% of the total construction value or around US$ 6.1 million. Therefore, if the hammer pile method is maintained, the potential delay is 110 days, or the contractor has a total penalty of around US$ 671 thousand with a penalty of 1 per mile of the contract value per day. Based on the calculation of the pile driving construction value on the XYZ Shopping Mall project, the rental and operational costs of HSPD equipment are 25% higher than those of hammer piles, about US$ 636 thousand and US$ 509 thousand, respectively.

The risk factor for low labor performance in the project has the second-highest impact on this study. This risk factor received an RPN of 210. This indicates that this factor is in the high-risk category. According to expert judgment, excessive breaks during the eight-hour working period were the obstacles caused by low labor performance that contributed to construction delays in the case study of the shopping mall project. For example, the HSPD capacity is 34 piles per day, but the project or case study has a high achievement gap. This project only reaches 19 or 24 piles per day. The problem of this low labor performance was a lack of induction and direction before starting work, followed by a lack of regular monitoring during work implementation. To mitigate the risk, daily induction, briefing, and daily targets for workers must be conducted. Furthermore, the supervisor monitors not only the ongoing activity but also the daily results.

The lack of professional staff is the third highest risk factor in shopping mall construction. This risk factor had an RPN of 192, which is still in the high category. An in-depth discussion with an expert identified the reason for the lack of professional staff in the case study team of the shopping mall project. The first cause is the staff's soft and hard skills. Although they passed the job interview during recruitment, the interviewer did not fully understand the soft and hard skills of the applicants. Second, the level of professionalism gained from previous work experience was totally different from the behavior of working in a shopping mall or as a fresh graduate. One direct factor delaying this project was the late provision of shop drawings by the main contractor to workers in the field. This occurred because the staff simultaneously handled several project drawings. Therefore, this problem needs mitigation or appropriate handling. Some ways to mitigate this risk include conducting soft and hard skill tests during the recruitment process. The senior supervisor must provide guidance to junior employees during the initial adaptation to the desired work culture. Furthermore, new employees could improve their performance by providing training and guidance to staff.

4. Conclusions

This study proved clearer results regarding the value of risk measurement in a shopping mall construction project. The VERA method integration approach provides holistic analysis results that consist of assessing the main function of project risk measurement, obtaining input for risk mitigation that impacts the efficient project on schedule, and achieving appropriate quality. Risk management in a construction project is crucial for achieving performance; thus, technical understanding is required through the formation of a professional team. Precisely project risk identification made the team formation needs optimal. This study demonstrated the effectiveness of the VERA method in identifying and addressing risk factors associated with the construction of a mall. FMEA prioritizes risk management, such as the potential for flooding due to weather that impacts the delay in the lower structure construction implementation, as in the case study. In addition, handling potential risks requires a cause-and-effect relationship through integrated mapping in the FAST diagram. The mapping results provide a complete picture for decision-making, namely, risk management is not only one priority but also has links with other risks, such as increasing the workforce capacity in the case study. The case study's time savings through risk management reached 120 days because selecting a work method appropriate to weather had a significant impact not only on risk measurement but also on proving construction implementation time. This was done through a comparison between maintaining the existing method, which had an impact on project delays, and replacing the technology with a technology appropriate to weather conditions, so that the foundation work could still be carried out even though it rained. However, the replacement of equipment compensated for the project implementation costs. The calculation results showed that the technology change had an impact on increasing costs of US$ 127 thousand or 25% when compared to the technology according to the initial plan. If the comparative calculation through the incremental cost process against the penalty cost due to project delays, which reached US$ 671 thousand, then changing the work method was still an option because it would save losses of up to US$544,000. Force majeure is a great concern, especially in basement structures of shopping mall projects. The presence of groundwater levels and the importance of weather forecasts are factors in risk management success. This capability has a significant impact on the time and cost of project performance. Several technical recommendations have been provided for risk mitigation, such as collaboration with the National Weather Forecasting Agency and the use of perimeter gutters to channel water technology. Moreover, the risk of a lack of productive and professional resources is a particular concern for shopping mall project stakeholders in recruitment selection, regular training, and mentoring from senior leaders to junior employees. The case study demonstrates that managing risks to achieve potential benefits is hampered by limited workforce capacity in new technology. Therefore, the case study provides lessons learned for future project management: improving workforce skills takes time to achieve cost efficiency. FMEA is superior in assessing potential risks because it provides a description and ranks risks from high to low priority. VE can measure the importance of the added value from risk management alternatives related to the time and cost of construction work. However, this research is still limited to shopping mall construction projects, so further research is recommended to be conducted in other construction industry sectors to enrich knowledge about risks in several types of construction. Based on these research results, there are suggestions for the further development of this research to be even better: Expand the location review by adding several research locations to see the comparison of dominant risks from each shopping mall location, and further analysis of dominant risk factors is needed to determine the losses incurred and delays experienced.

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Author Contributions

VB contributed to the conceptualization, research planning, structural analysis, critical review, and writing – original draft preparation, review, & editing. FDF was supported the experiment design, investigation, resources, and data collection. IC was responsible for the methodology, supervision of the study, and validation.

Conflict of Interest

The authors declare no conflicts of interest.

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