

ANALYSIS AND MITIGATION OF DELAY RISKS IN THE CONSTRUCTION OF THE CENTRAL SURGICAL INSTALLATION BUILDING USING THE HOUSE OF RISK METHOD

Hafnidar Rani*, Tamalkhani Syammaun, Firmansyah Rachman and Andhika Cahyadi

Received: February 19, 2025; Revised: April 01, 2025; Accepted: June 26, 2025

Abstract

One of the ongoing construction projects in Banda Aceh City is the Central Surgical Installation Building at Meuraxa Regional General Hospital. However, based on contractor observations, this project has experienced delays beyond the planned schedule. This study identifies the factors contributing to these delays using the House of Risk (HOR) method and explores mitigation strategies. The research involved a questionnaire survey with 20 respondents, which included contractors and supervising consultants. The study examined six key delay factors: planning and scheduling (E1), work documents (E2), control systems (E3), resource readiness (E4), financial delays (E5), and material delays (E6). The HOR Phase 1 analysis identified three primary risk agents: inaccurate project specifications (A1) with an ARP value of 180, slow administrative processes (A2) with 128, and unreliable cost estimation (A3) with 108, all contributing significantly to project delays. In HOR Phase 2, five mitigation strategies were proposed, including improving communication with the project owner (PA1), expediting administrative processes (PA2), developing a detailed cost estimation framework (PA3), optimizing material procurement and supplier coordination (PA4), and allocating additional workforce and equipment (PA5). These actions aim to minimize risks and enhance project efficiency. By implementing these mitigation strategies, construction delays can be effectively reduced, ensuring timely project completion. This study highlights the importance of structured risk management in construction projects and provides valuable insights for contractors, project managers, and policymakers.

Keywords: Construction Project; House of Risk; Mitigation; Project Delay

Department of Civil Engineering, Universitas Muhammadiyah Aceh, Banda Aceh, Indonesia. Email: hafnidar@unmuha.ac.id; tamalkhani@unmuha.ac.id; firmansyah@unmuha.ac.id; andikamaster46@gmail.com*

** Corresponding author*

DOI: <https://doi.org/10.55766/sujst8738>

Suranaree J. Sci. Technol. 32(6):010384(1-12)

Introduction

Every construction project is planned with a detailed schedule, outlining when the project is expected to begin, the sequence of activities, and the anticipated completion date to ensure timely execution. However, numerous challenges such as resource shortages, improper allocation, procurement delays, and inefficient project management can disrupt the execution phase, leading to significant delays (Ullah *et al.*, 2024; Al-Tameemi, 2025). These delays are particularly concerning in healthcare infrastructure projects, where setbacks can impact public service delivery and patient care quality (Yang *et al.*, 2022). Delays in construction projects are often attributed to factors such as poor project management, insufficient resources, unexpected site conditions, and adverse weather (Nadeem *et al.*, 2023; Pregina and Kannan, 2024). Such delays can result in cost overruns, disputes among stakeholders, and reputational damage to construction firms (Shash and Musabih, 2022).

The Central Surgical Installation Building at Meuraxa Regional General Hospital in Banda Aceh is a critical healthcare project aimed at enhancing medical services in the region. With a contract value of IDR 13,075,957,000 and a planned duration of 210 calendar days, timely completion is essential. However, observations from the contractor and supervising consultants indicate significant deviations from the original schedule due to various delay factors, including planning inefficiencies, procurement bottlenecks, and administrative constraints (Kumar and Kumari, 2025). Delays in the construction of healthcare facilities can have far-reaching consequences, including limited access to essential health services and disruptions in hospital operations (Alrasheed *et al.*, 2023).

Despite the well-documented risks of construction delays, limited research has focused on a structured risk assessment framework tailored to healthcare infrastructure projects in developing regions. Existing studies often highlight general construction risks but lack a systematic approach to quantifying and prioritizing specific risk agents that contribute to delays (Kim and Kim, 2025). Furthermore, conventional mitigation strategies are frequently reactive rather than proactive, leading to inefficiencies in delay management (Won *et al.*, 2024). Effective risk identification and mitigation are crucial to improving project performance and ensuring timely completion (Almashhour *et al.*, 2025).

To address this gap, this study applies the House of Risk (HOR) methodology to systematically assess and mitigate delay risks in the

Central Surgical Installation Building project. The research involves surveying key stakeholders, including contractors and supervisory consultants, to evaluate six primary delay factors: planning and scheduling, work documents, control systems, resource readiness, financial constraints, and material procurement (Daoud *et al.*, 2023). Risk agents will be prioritized using the Aggregate Risk Potential (ARP) metric, followed by the development of mitigation strategies based on the Effectiveness-to-Difficulty Ratio (ETDk) (Al-Attabi, 2025). This approach ensures a structured and data-driven method to address project delays effectively. By applying HOR to this case, the study aims to pinpoint critical risk agents and propose actionable mitigation strategies that can enhance project efficiency. The findings will contribute to improving risk management practices in healthcare infrastructure projects, ensuring more effective planning and execution while minimizing costly delays (Amaechi *et al.*, 2025).

This study aims to identify key factors contributing to delays in the construction of the Central Surgical Installation Building at Meuraxa Regional General Hospital, analyze and prioritize the risk agents associated with these delays using the House of Risk (HOR) methodology, and develop effective mitigation strategies to minimize risks and enhance project efficiency. Additionally, the study seeks to provide recommendations for improving risk management practices in healthcare construction projects, particularly in developing regions, to ensure timely project completion and optimal resource utilization (Shash and Musabih, 2022; Daoud *et al.*, 2023).

Literature Review

Factors Causing Delays in Construction Projects

Construction projects are often susceptible to delays due to a variety of factors, which can range from external influences such as weather conditions to internal project management issues. Several studies have explored the primary causes of delays, providing insight into how these factors affect the timely completion of construction projects.

One of the most frequently identified causes of construction delays is poor project planning and scheduling. Al-Tameemi (2025) argue that inadequate scheduling can lead to misaligned project timelines, which ultimately results in delays. This is particularly true for complex projects that require careful coordination of resources, tasks, and

timelines. Similarly, poor coordination between project stakeholders, including contractors, consultants, and suppliers, has also been found to be a significant contributor to project delays (Bruni and Hazir, 2024). A study by Nadeem *et al.* (2023) found that delays in obtaining necessary approvals and permits, as well as slow decision-making processes, often exacerbate the situation.

Another significant factor contributing to delays is resource allocation. Daoud *et al.* (2023) highlight that improper allocation of resources such as labor, materials, and equipment can lead to bottlenecks in the construction process, thus extending the overall project duration. For example, shortages in material supply or delays in material delivery are common causes of project delays (Yang *et al.*, 2022). Similarly, inadequate labor resources, including skilled workers, can further disrupt the project schedule and delay the completion date (Nadeem *et al.*, 2023).

External factors, such as adverse weather conditions and unforeseen site conditions, also play a substantial role in project delays. According to Tang *et al.* (2020), projects often face delays due to weather-related issues such as heavy rainfall, flooding, or extreme temperatures that halt construction activities temporarily. Other unforeseen circumstances, such as environmental and geological issues at the site, can also delay construction progress (Amaechi *et al.*, 2025).

Financial issues are another major factor contributing to delays. Insufficient cash flow or delays in payments can result in stoppages in construction activities, as contractors may lack the funds to continue work or purchase materials (Almashhour *et al.*, 2025). This issue is often linked to the client's inability to meet financial obligations, further exacerbating delays in project completion (Bruni and Hazir, 2024).

Risk Management in Construction Projects

Risk management in construction projects is a critical practice aimed at identifying, analyzing, and mitigating the factors that can lead to delays or cost overruns. Several methodologies have been proposed and employed to address risks in construction projects. Among these, the House of Risk (HOR) methodology has been widely recognized for its effectiveness in identifying risks and proposing mitigation strategies (Rani *et al.*, 2024).

The House of Risk (HOR) method, developed by Shash and Musabih (2022), is a structured approach to risk management that helps identify and prioritize risks in construction projects. This method involves two main phases: Phase 1, where risk

events are identified and assessed for severity and likelihood; and Phase 2, where mitigation actions are developed based on their effectiveness and the difficulty of implementation (Almashhour *et al.*, 2025). HOR allows project managers to focus on the most critical risks and determine the most effective actions for managing them, thereby minimizing their impact on project timelines and costs (Won *et al.*, 2024 ; Al-Attabi, 2025).

Several studies have shown that the House of Risk method provides a systematic framework for managing risks in construction projects. For example, Almashhour *et al.* (2025) applied HOR in the analysis of construction projects and found it to be a valuable tool for identifying and mitigating risks associated with project delays. Their study demonstrated how HOR could assist project managers in focusing on high-priority risks, such as delays in material procurement, inadequate resource allocation, and poor scheduling. By doing so, it helps ensure that projects are completed on time and within budget.

Moreover, research has also suggested that the HOR methodology can enhance communication and coordination among project stakeholders. Almashhour *et al.* (2025) argue that effective communication between contractors, clients, and suppliers is essential for ensuring smooth project execution. The HOR method aids in identifying potential communication gaps and helps develop strategies to address these gaps, thus reducing the likelihood of misunderstandings that could lead to delays.

The effectiveness of HOR in mitigating construction project risks has also been highlighted in studies focused on large-scale infrastructure projects. A study by Won *et al.*, (2024) demonstrated the successful application of HOR in managing risks associated with the construction of bridges, where it identified key factors such as material delivery delays and labor shortages. By implementing mitigation measures based on the HOR analysis, the project was able to reduce delays significantly and complete the construction on schedule.

Risk Analysis Methods

Risk analysis is a process to analyze both qualitatively and quantitatively the impact of risk (severity) and the probability of risk (occurrence) on the goals and objectives of a project. The purpose of risk analysis is to categorize and separate risks between hazardous and insignificant risks, creating a risk profile map according to their rankings. The result will serve as the foundation for further risk analysis and mitigation actions.

Hazard Identification Risk Assessment and Determining Control (HIRADC)

HIRADC is a method used within the Occupational Health and Safety Management System (OHSMS), primarily focusing on the planning phase. This method involves three key stages: hazard identification, risk assessment, and control determination. The process starts with hazard identification, where potential hazards present in the work environment are recognized. Hazards can range from physical and chemical dangers to biological, ergonomic, and psychosocial risks that could potentially harm workers or the environment. Following this, a thorough risk assessment is conducted to evaluate the potential harm each identified hazard could cause and the likelihood of its occurrence. This allows for the prioritization of risks based on their severity and frequency. Finally, control determination is carried out to establish measures that can either eliminate or minimize these risks. These controls may include engineering solutions, administrative changes, or the use of personal protective equipment (PPE), depending on the severity and nature of the risk. The main objective of HIRADC is to proactively manage risks by identifying and assessing hazards, followed by implementing effective control measures. This helps prevent accidents, injuries, and damage to property, while ensuring compliance with safety standards and creating a safer work environment (Salah *et al.*, 2023; Rahim *et al.*, 2024; Chou *et al.*, 2025).

The identified hazards and their corresponding risk assessments are summarized in Table 1, which outlines the severity and occurrence levels along with proposed control measures.

Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a systematic method used to examine the causes of defects or failures in production processes. It is primarily employed to evaluate the priority of risks

associated with potential failures and to identify preventive actions to avoid these failures. The FMEA method uses three key parameters: severity (S), occurrence (O), and detection (D). These parameters help assess the potential risks of accidents, with severity indicating the seriousness of the impact, occurrence representing the likelihood of the failure happening, and detection reflecting how likely it is that the failure will be detected before causing harm (Salah *et al.*, 2023).

FMEA helps identify failure modes early in the design and production stages, which can then be addressed to prevent accidents or system breakdowns. It is particularly useful for maintaining alternative designs that are more reliable and safer during the design phase of a product or process. The ratings for severity and occurrence are essential in determining the impact and frequency of potential failures, which are then used to rank risks and identify appropriate mitigation measures. The analysis generates a Risk Priority Number (RPN), calculated by multiplying the severity, occurrence, and detection ratings, which helps prioritize actions based on the highest risk. By addressing high RPN values, organizations can focus on eliminating or reducing critical risks before they result in failures (Liou *et al.*, 2026).

Severity Rating Scale

The severity scale in FMEA determines the impact or consequences of a potential failure on the system. The higher the severity, the more serious the failure would be.

The severity rating scale used in the Failure Mode and Effect Analysis (FMEA) is presented in Table 2.

Occurrence Rating Scale

The occurrence scale in FMEA measures the frequency or probability of the failure happening. A higher value indicates a higher probability of occurrence.

Table 1. HIRADC Risk Assessment Table

Hazard	Risk Assessment		Risk Control Measures
	Hazard	Risk Assessment	
Physical Hazards (e.g., machinery)	High	Moderate	Regular maintenance, proper training, PPE (e.g., gloves, safety goggles)
Chemical Hazards (e.g., exposure to toxic chemicals)	High	Low	Proper storage, ventilation, protective clothing, safety protocols
Ergonomic Hazards (e.g., repetitive motion)	Moderate	High	Ergonomic workstations, regular breaks, correct posture education
Psychosocial Hazards (e.g., stress, harassment)	Moderate	Moderate	Employee support programs, clear anti-harassment policies, stress management workshops
Biological Hazards (e.g., exposure to bacteria or viruses)	High	Low	Hygiene practices, vaccinations, personal protective equipment

Table 2. Severity Rating Scale

Rating	Effect	Severity Effect
10	Hazardous without warning (HWOW)	Very high severity, risk affects system safety without any prior warning.
9	Hazardous with warning (HWW)	Very high severity, risk affects system safety but with some warning.
8	Very High (VH)	System cannot operate; causes damage without compromising safety.
7	High (H)	System cannot operate due to equipment failure.
6	Moderate (M)	System cannot operate due to minor damage.
5	Low (L)	System cannot operate but no damage occurs.
4	Very Low (VL)	System operates with significant performance degradation.
3	Minor (MR)	System operates with slight performance reduction.
2	Very Minor (VMR)	System operates with minimal disruption.
1	None (N)	No effect.

Table 3. Occurrence Rating Scale

Rating	Probability of Occurrence	Occurrence Frequency
10	Very High (VH)	Failure is almost inevitable, occurring more than once in every two occurrences.
9	High (H)	Failure occurs frequently, approximately once in every three occurrences.
8	High (H)	Failure occurs approximately once in every eight occurrences.
7	High (H)	Failure occurs once in every 20 occurrences.
6	Moderate (M)	Failure happens occasionally, about once in every 80 occurrences.
5	Moderate (M)	Failure occurs about once in every 400 occurrences.
4	Moderate (M)	Failure occurs about once in every 2000 occurrences.
3	Low (L)	Failure is rare, occurring about once in every 15,000 occurrences.
2	Low (L)	Failure occurs about once in every 150,000 occurrences.
1	Very Low (VL)	Failure is extremely rare, occurring less than once in every 2 occurrences.

The frequency of occurrence for each potential failure is described in Table 3, which helps to quantify the likelihood of each risk event.

House of Risk (HOR) Method

The House of Risk (HOR) method is a structured approach to manage and mitigate risks within a system or project by identifying and addressing risk agents—those factors that contribute to the occurrence of risk events. The HOR method is composed of two main phases, which work sequentially to ensure effective risk management.

HOR Phase 1: Identifying Risk Causes and Prioritizing Risks

The first phase of HOR focuses on identifying risk causes (also referred to as risk agents) and determining which ones are most critical to the overall risk profile. These risk agents are then assessed using an Aggregate Risk Priority (ARP), which allows prioritization based on the severity and likelihood of each risk event. The objective of this phase is to ensure that the most significant risks are identified and addressed first, providing a clear structure for risk mitigation strategies. The ARP helps project teams to focus on the risk agents that could have the most damaging impacts, facilitating better resource allocation and management (Hadi *et al.*, 2020; Hosseini and Javid, 2025).

HOR Phase 2: Identifying Prevention Actions and Mitigation Strategies

In the second phase, the focus shifts to identifying effective prevention actions for the prioritized risk agents. These actions must be selected based on their ability to mitigate risks while considering factors like available resources and the difficulty of implementation. The goal is to ensure that the prevention actions are both effective and feasible. This phase helps project managers devise practical strategies that reduce risk likelihood while ensuring they align with the project's objectives and constraints (Hadi *et al.*, 2020; Hosseini and Javid, 2025). The HOR method ensures that high-priority risks are mitigated efficiently, which is particularly important for projects with limited resources and strict timelines.

The HOR method has been successfully applied in a variety of industries, including construction, manufacturing, and service sectors. It helps to manage not only project risks but also operational risks, ensuring that risk events are controlled and managed in an organized manner (Xia *et al.*, 2021).

In summary, the House of Risk method provides a structured framework that assists in identifying risk causes, prioritizing them, and implementing effective prevention actions. This ensures that the most critical risks are addressed early and efficiently.

Pareto Diagram (Pareto Analysis)

Pareto Diagram helps identify and address the most significant issues that impact the entire project. The Pareto principle states that 80% of the problems are caused by 20% of the causes. By analyzing the frequency of problems, the Pareto diagram helps prioritize the most critical issues to address first (Irfanto and Charolin, 2024).

Probability Impact Matrix

The Probability Impact Matrix is used to assess risks qualitatively. It evaluates risks based on two components: the probability of occurrence and the impact it could have. This method helps classify risks and determine priorities based on their probability and severity (Singh *et al.*, 2023).

Application of HOR in Delay Risk Management

The use of the House of Risk method has been extensively explored in various construction sectors, including healthcare infrastructure. Healthcare projects, due to their complexity and the critical nature of the facilities being built, face unique challenges that make risk management even more vital. In particular, delays in healthcare construction projects can result in significant consequences, including delayed access to medical services and increased public health risks (Das, 2024). Therefore, the use of HOR in healthcare projects is crucial to identifying and mitigating risks that could negatively affect project timelines and quality.

Recent studies, such as those by Amaechi *et al.* (2025), demonstrate the relevance of applying HOR in the context of hospital construction projects, where delays are often caused by resource shortages, delays in material procurement, and financial constraints. The application of the HOR method helps stakeholders prioritize these risks and implement effective mitigation strategies, ensuring that construction deadlines are met. By using HOR, construction project managers are better equipped to make informed decisions, anticipate potential delays, and address problems before they escalate into major issues (Nadeem *et al.*, 2023).

Summary of Key Findings

The literature on construction project delays underscores the complexity of risk management and the need for structured approaches to mitigate delays in project timelines. Several factors contribute to delays in construction, with common ones including poor project planning and scheduling, inadequate resource allocation, weather conditions, and financial issues (Bruni and Hazir, 2024).

The House of Risk (HOR) methodology has been demonstrated as an effective tool for identifying and assessing risks associated with

construction delays. By focusing on risk severity and occurrence, the HOR method enables project managers to prioritize risks and implement targeted mitigation strategies. Studies by Almashhour *et al.* (2025); Won *et al.* (2024) confirm that HOR can significantly improve risk management processes, especially in large-scale projects, ensuring that risks are managed effectively to meet project deadlines.

In particular, healthcare construction projects, such as the construction of hospital facilities, present unique challenges where delays can have serious consequences on public health and service delivery. As evidenced by Alrasheed *et al.* (2023); Amaechi *et al.* (2025), applying the HOR method to healthcare construction projects helps in addressing these challenges by identifying critical risks early in the project lifecycle, thereby reducing delays and ensuring timely completion.

This literature review establishes the importance of using the House of Risk methodology to manage delay risks in construction projects, particularly in healthcare infrastructure. The findings provide a solid foundation for the application of HOR in the Central Surgical Installation Building Project at Meuraxa Regional General Hospital, where timely completion is crucial to improving healthcare services.

Methodology

This study adopts a structured approach to risk identification, assessment, and mitigation in construction projects using three key methods: Hazard Identification, Risk Assessment, and Determining Control (HIRADC), Failure Mode and Effects Analysis (FMEA), and the House of Risk (HOR) method. These methods ensure a systematic evaluation of potential hazards, prioritization of risks, and implementation of effective mitigation strategies.

The HIRADC method is an essential part of the Occupational Health and Safety Management System (OHSMS) that focuses on preventing workplace accidents by identifying hazards, assessing risks, and determining appropriate control measures. This study applies HIRADC to recognize potential dangers in construction activities, evaluate their probability and severity, and implement mitigation strategies to reduce risks (Chou *et al.*, 2025).

The FMEA method is applied to systematically analyze potential failure modes in construction activities. Risks are prioritized by calculating the Risk Priority Number (RPN), which is determined by multiplying Severity (S), Occurrence (O), and Detection (D). This allows

decision-makers to focus on the most critical failure modes and implement targeted mitigation strategies (Salah *et al.*, 2023).

The HOR method is a proactive risk management approach divided into two phases: HOR 1 (identification of risk agents and calculation of the Aggregate Risk Priority score) and HOR 2 (selection of effective mitigation actions). The ARP score is computed using the formula: $ARP = \text{Severity} \times \text{Occurrence} \times \text{Correlation}$, ensuring that the most significant risks are addressed first (Xia *et al.*, 2021).

The correlation (R) value used in this study ranges from 1 to 10, where 1 represents a very weak relationship and 10 indicates a very strong correlation between the risk agent and the associated delay event. This scale was adapted based on expert judgment and follows a modified approach inspired by the traditional FMEA framework as applied to risk assessment in construction (Hadi *et al.*, 2020; Hosseini and Javid, 2025). During data collection, respondents assessed the degree of influence each risk agent had on various delay events, and these values were then used to calculate the ARP.

A structured HOR flowchart (Figure 1) illustrates the step-by-step process of risk identification, prioritization, and mitigation.

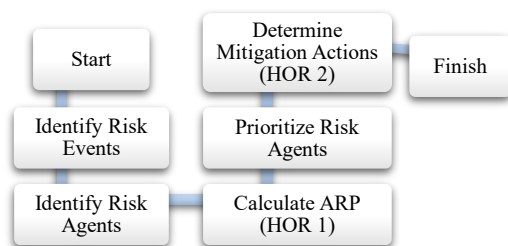


Figure 1. House of Risk (HOR) Flowchart

As shown in Figure 1, the HOR process starts with identifying risk events and risk agents. The next step involves evaluating these agents based on severity, occurrence, and detection, followed by calculating the ARP value. The highest-priority risks are then addressed in HOR 2 by formulating mitigation strategies, ensuring an effective risk management process.

By integrating HIRADC, FMEA, and HOR, this study provides a comprehensive framework for risk management in construction projects. These methods enable construction managers to systematically assess hazards, prioritize risks, and implement effective control measures, ultimately enhancing project safety, reducing delays, and minimizing financial losses.

Participants for this study include project stakeholders such as contractors, site supervisors, and project managers involved in the Central Surgical Installation Building construction. The selection is based on purposive sampling, ensuring that only those with direct project involvement contribute to data collection. Primary data is collected through structured interviews and surveys, while secondary data, such as project reports and risk assessment records, is analyzed to complement the findings.

Results and Discussion

Characteristics of Respondents

Table 4 categorizes the respondents based on gender, age, education level, job position, and work experience.

The majority of the respondents were male (90%), while female respondents accounted for only

Table 4. Recapitulation of Respondent Characteristics

Category	Subcategory	Number of Respondents	Percentage [%]
Gender	Male	18	90
	Female	2	10
Age	20 - 35 years old	14	70
	36 - 45 years old	4	20
	> 45 years old	2	10
Education Level	Diploma (D3/D4)	4	20
	Bachelor's Degree (S1)	13	65
	Master's/Doctoral Degree (S2/S3)	3	15
Job Position	Project Manager	1	5
	Quality Engineer	3	15
	Quantity Surveyor	3	15
	Site Manager	3	15
	Inspector	2	10
	Supervisor	3	15
	Other Positions	5	25
Work Experience	< 5 years	8	40
	5 - 10 years	9	45
	> 10 years	3	15

10%. This reflects the typical gender composition in the construction sector, where male dominance is prevalent. Most respondents (70%) were between 20-35 years old, indicating a predominance of young professionals in the project. Meanwhile, 20% were between 36-45 years old, and 10% were over 45 years old. The educational background of the respondents varied, with 65% holding a bachelor's degree (S1), 20% having a diploma (D3), and 15% holding a master's or doctoral degree (S2/S3). This suggests that the workforce is well-educated and equipped with the necessary technical expertise. The respondents held different positions within the project team. Project managers accounted for 5%, while quality engineers, quantity surveyors, and site managers each represented 15% of the total respondents. Inspectors and supervisors were also included in the study, each contributing between 10% and 15%. The respondents' work experience ranged from less than 5 years (40%), 5-10 years (45%), to more than 10 years (15%). This suggests a balanced workforce, combining experienced professionals with younger professionals who bring new perspectives. These demographic insights are crucial in understanding the respondents' perspectives on the project's challenges and risk management processes.

Identification of Delay Risk Factors

The construction of the Central Surgical Installation Building at Meuraxa Regional General Hospital has encountered several delays. To systematically analyze the causes of these delays, this study applies the House of Risk (HOR) method, which consists of two phases: (1) identifying risk agents and prioritizing them based on their impact, and (2) formulating mitigation strategies to reduce these risks.

The prioritization of risk agents based on the Aggregate Risk Priority (ARP) is illustrated in Figure 2, corresponding to the data summarized in Table 5.

The Pareto analysis in Figure 2 categorizes the most significant risk causes affecting the project, following the 80/20 principle, where a small number of risk factors contribute to the majority of delays. The analysis reveals that administrative delays,

material shortages, and financial issues are the primary contributors to project inefficiencies. By prioritizing the mitigation of these critical risks, project managers can significantly reduce delays and enhance productivity. The cumulative percentage curve further illustrates how addressing the top-ranked risk factors can have the most substantial impact on improving project timelines.

Figure 3 illustrates the various risk events that contribute to project delays in the construction of the Central Surgical Installation Building at Meuraxa Regional General Hospital. Among the identified risks, material delays account for the highest percentage, followed by labor shortages, financial issues, and weather-related disruptions. These findings highlight the importance of effective project planning, resource management, and risk mitigation strategies to ensure smooth project execution.

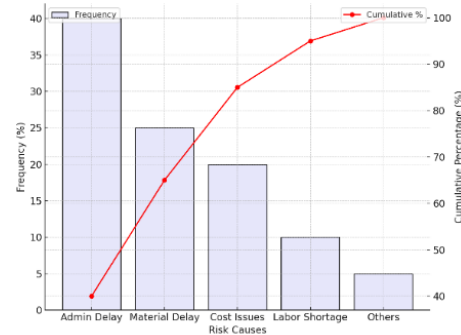


Figure 2. Pareto Analysis of Risk Causes

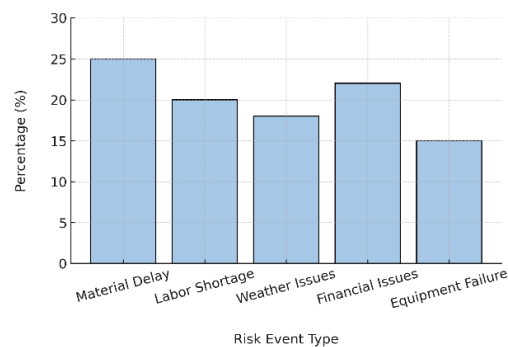


Figure 3. Risk Event Identification

Table 5. House of Risk Phase 1 - Prioritization of Risk Agents

Risk Agent Code	Risk Agent	Occurrence (O)	Severity (S)	Correlation (R)	ARP	Rank
A1	Inaccurate project specification data	5	4	9	180	1
A2	Slow administrative processes	4	4	8	128	2
A3	Unreliable cost estimation	4	3	9	108	3
A4	Delay in material procurement	3	3	7	63	4
A5	Inadequate resource allocation	3	2	6	36	5

Table 6. House of Risk Phase 2 - Risk Mitigation Strategies

Risk Agent Code	Mitigation Strategy	Effectiveness (E)	Difficulty (D)	ETDk	Priority Rank
A1	Improve communication with project owner on planning	9	3	3.00	1
A2	Expedite administrative processes through digitization	8	3	2.67	2
A3	Develop a detailed cost estimation framework	7	3	2.33	3
A4	Optimize material procurement and supplier coordination	6	3	2.00	4
A5	Allocate additional workforce and advanced equipment	5	3	1.67	5

House of Risk (HOR) Phase 1: Identification and Prioritization of Risk Agents

In the first phase of the HOR method, risk agents that contribute to project delays were identified based on survey responses from contractors and supervisory consultants. Each risk agent was evaluated based on its severity (S), occurrence (O), and correlation with delay events (R). The Aggregate Risk Priority (ARP) value was then calculated to determine which risk agents had the highest impact on project delays.

Table 5 presents the prioritization of risk agents based on their ARP values.

The results indicate that inaccurate project specification data (ARP = 180), slow administrative processes (ARP = 128), and unreliable cost estimation (ARP = 108) are the top three risk agents contributing to project delays. These issues can lead to miscommunication, extended approval times, and financial miscalculations, ultimately affecting project timelines.

The Aggregate Risk Priority (ARP) values were calculated to determine the most critical risks that require immediate attention. The results indicate that inaccurate project specifications (A1), slow administrative processes (A2), and unreliable cost estimation (A3) are the top-ranked risk agents. Addressing these high-priority risks through targeted mitigation strategies can significantly reduce project delays.

House of Risk (HOR) Phase 2: Development of Risk Mitigation Strategies

The second phase of the HOR method focuses on formulating mitigation strategies to address the highest-priority risk agents. Each mitigation strategy was assessed based on its effectiveness (E) in reducing the likelihood of delays and the difficulty level (D) of implementation. The Effectiveness-to-Difficulty Ratio (ETDk = E / D) was then calculated to prioritize feasible actions.

The identified mitigation strategies and their Effectiveness-to-Difficulty Ratios are presented in

Table 6, summarizing the results of the HOR Phase 2 analysis.

The highest-priority mitigation strategies identified in this study include enhancing communication with the project owner (ETDk = 3.00) to ensure that project specifications are clear and aligned from the start, digitizing administrative processes (ETDk = 2.67) to reduce paperwork delays and approval bottlenecks, and developing a more precise cost estimation framework (ETDk = 2.33) to improve budget planning and prevent financial overruns. By implementing these strategic mitigation actions, the risk of delays can be significantly reduced, leading to smoother project execution and improved efficiency.

The highest-priority actions include enhancing communication with project owners, digitizing administrative processes, and improving cost estimation accuracy. These mitigation strategies are expected to minimize project risks and improve overall project performance. By implementing these measures, construction delays can be effectively managed, ensuring the timely completion of the project.

This study applied the House of Risk (HOR) method to systematically analyze and mitigate risks contributing to delays in the construction of the Central Surgical Installation Building at Meuraxa Regional General Hospital. The findings reveal that inaccurate project data, administrative inefficiencies, and poor cost estimation are the most critical risk agents affecting project timelines. The proposed mitigation strategies, including improving project communication, digitizing administration, and refining cost estimation methods, are expected to address these issues effectively, ensuring better project management and execution.

By integrating the HIRADC, FMEA, and HOR methods, this research provides a comprehensive risk management framework that offers valuable insights for construction managers, contractors, and policymakers. These findings highlight the importance of proactive risk identification and

mitigation in preventing project delays and enhancing overall project performance, ultimately contributing to a more efficient and well-managed construction process.

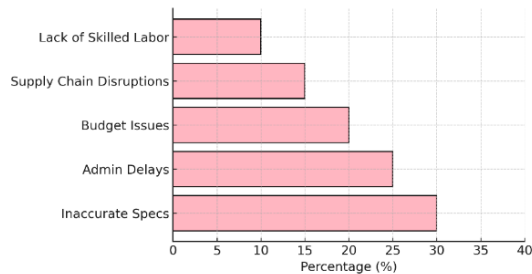


Figure 4. Dominant Risk Causes

Figure 4 presents the primary causes of construction project delays based on the analysis of survey responses. Inaccurate project specifications emerged as the most significant risk factor, leading to miscommunication, rework, and scheduling issues. Administrative delays and budgeting inaccuracies were also identified as major contributors to project inefficiencies. Other risk factors, such as supply chain disruptions and labor shortages, further emphasize the need for improved project coordination and strategic planning.

The contribution of Figure 4 lies in its ability to visually validate and reinforce the findings from the House of Risk Phase 1 analysis (Table 5). It provides a graphical summary of stakeholder perspectives, which confirms the quantitative prioritization of risk agents such as A1, A2, and A3. By aligning empirical data with visual stakeholder insights, Figure 4 strengthens the argument that mitigation strategies should be focused on these critical areas. Thus, this figure supports the research objectives by bridging data-driven analysis with practitioner perception, ensuring that the recommendations are both evidence-based and practically relevant.

Discussion

The results of this study highlight the significant factors contributing to delays in the construction of the Central Surgical Installation Building at Meuraxa Regional General Hospital. The application of the House of Risk (HOR) method allowed for a structured analysis of risk agents and the development of targeted mitigation strategies. This discussion section further explores the implications of the findings, compares them with previous research, and outlines their practical relevance for project management.

Practical Implications for Construction Project Management

The mitigation strategies proposed in this study offer practical solutions for reducing delays and improving project execution. The recommendation to enhance communication between stakeholders is critical, as unclear specifications often lead to project revisions and scheduling conflicts. Establishing regular coordination meetings and digital reporting systems could ensure that all stakeholders are aligned throughout the project lifecycle.

The adoption of digital administrative processes can also play a crucial role in improving project efficiency. By implementing electronic document management systems, approval processes can be expedited, reducing unnecessary waiting times. Many construction firms have successfully adopted Building Information Modeling (BIM) and other digital tools to streamline project workflows, a strategy that could be beneficial in similar hospital construction projects.

Additionally, the refinement of cost estimation methods is essential to preventing financial mismanagement. The development of detailed cost breakdowns and risk-adjusted budgets can help project managers anticipate potential financial risks and allocate resources more effectively. By incorporating risk-based cost estimation models, construction projects can minimize unexpected cost overruns, ensuring that financial planning remains accurate and reliable.

Limitations of the Study

While this study provides valuable insights into risk mitigation in construction projects, certain limitations should be acknowledged. First, the sample size of respondents was limited to contractors and supervisory consultants involved in a single hospital construction project. Future research should incorporate a broader range of stakeholders, including government officials, financial planners, and material suppliers, to gain a more comprehensive understanding of risk factors.

Second, the effectiveness of the proposed mitigation strategies has not yet been tested in a real-world implementation. Although the strategies are based on quantitative risk assessment methods (HIRADC, FMEA, and HOR), further research is required to evaluate their impact on actual project timelines and cost efficiency. Future studies could conduct longitudinal analyses to track the effectiveness of these risk mitigation strategies over time.

Lastly, external factors such as weather conditions, policy changes, and supply chain disruptions were not extensively analyzed in this study. These factors can significantly impact construction timelines and should be explored further in future research.

Conclusions

This study applied the House of Risk (HOR) method to identify and mitigate key risk factors causing delays in the construction of the Central Surgical Installation Building at Meuraxa Regional General Hospital. The results indicate that procurement delays, administrative inefficiencies, and poor cost estimation were the primary contributors to project delays. To address these issues, enhancing stakeholder communication, digitizing administrative processes, and refining cost estimation frameworks were identified as the most effective mitigation strategies. While this study provides valuable insights into risk management for healthcare infrastructure projects, its scope is limited to a single project and a specific group of stakeholders. Future research should expand to different construction sectors and validate the proposed strategies through real-world implementation. By integrating structured risk assessment frameworks like HIRADC, FMEA, and HOR, construction projects can improve efficiency, minimize delays, and optimize resource allocation. The findings contribute to advancing risk management practices and offer practical recommendations for policymakers, contractors, and project managers in the construction sector.

Acknowledgement

The authors express their sincere gratitude to Meuraxa Regional General Hospital and the contractors and supervisory consultants involved in the Central Surgical Installation Building Project for their valuable cooperation and willingness to participate in this study.

References

- Al-Attabi, A.M.A.N. (2025). Toward delay mitigation in Iraqi construction project: Evaluating the causes and the implications. *Ain Shams Engineering Journal*, 16(10):103598. <https://doi.org/10.1016/j.asej.2025.103598>
- Almashhour, R., Al-Mhdawi, M.K.S., Daghfous, A., Qazi, A., and Ojiako, U. (2025). Traditional to sustainable risk management in the construction industry: A systematic literature review. *International Journal of Managing Projects in Business*, 18(3):528-565. <https://doi.org/10.1108/IJMPB-01-2025-0021>
- Alrasheed, K., Soliman, E., and Albader, H. (2023). Systematic review of construction project delays in Kuwait. *Journal of Engineering Research*, 11(4):347-355. <https://doi.org/10.1016/j.jer.2023.08.009>
- Al-Tameemi, K.S. (2025). The impact of schedule compression techniques on construction project timelines: A case study in Basrah, Iraq. *The Open Civil Engineering Journal*, 19. <https://doi.org/10.2174/0118741495360335241205110710>
- Amaechi, C.V., Reda, A., Beddu, S.B., Mohamed, D.B., Syamsir, A., Ja'e, I.A., Ullah, S., Xiaopeng, D., Huang, B., Wang, C., and Ju, X. (2025). A systematic literature review on knowledge for project risk management in construction. *Journal of Building Engineering*, 114:114261. <https://doi.org/10.1016/j.job.2025.114261>
- Bruni, M.E., and Hazir, Ö. (2024). A risk-averse distributionally robust project scheduling model to address payment delays. *European Journal of Operational Research*, 318(2):398-407. <https://doi.org/10.1016/j.ejor.2024.05.037>
- Chou, J.-S., Lin, T.-Y., Molla, A., and Lin, C.-C. J. (2025). Advanced risk management strategies for safety enhancement in temporary building construction works. *Journal of Safety Research*. <https://doi.org/10.1016/j.jsr.2025.08.003>
- Daoud, A.O., El Hefnawy, M., and Wefki, H. (2023). Investigating of critical factors affecting cost overrun and delays in Egyptian mega construction projects. *Alexandria Engineering Journal*, 83:326-334. <https://doi.org/10.1016/j.aej.2023.10.052>
- Das, D.K. (2024). Mitigating construction delays in Indian real estate projects through effective organizational and project management. *International Journal of Building Pathology and Adaptation*, 43(6):1423-1438. <https://doi.org/10.1108/IJBPA-08-2023-0109>
- Hadi, J.A., Febrianti, M.A., Yudhistira, G.A., and Qurtubi, Q. (2020). Identifikasi risiko rantai pasok dengan metode House of Risk (HOR). *Performa: Media Ilmiah Teknik Industri*, 19(2):85-94. <https://doi.org/10.20961/performa.19.2.46388>
- Hosseini, K., and Javid, Y. (2025). Enhancing risk assessment in sustainable construction projects: A hybrid neutrosophic-based decision making framework. *Journal of Cleaner Production*, 525:146395. <https://doi.org/10.1016/j.jclepro.2025.146395>
- Irfanto, R., and Charolin, E. (2024). Implementasi prinsip pareto pada pekerjaan perbaikan di proyek perumahan (Studi kasus: Proyek Perumahan di Kota Tangerang Selatan). *Indonesian Journal on Construction Engineering and Sustainable Development*, 7(1):47-53. <https://doi.org/10.25105/cesd.v7i1.20264>
- Kim, S.H., and Kim, Y.S. (2025). Quantitative analysis of schedule impact due to design changes in finishing construction work: A case study of office buildings. *KSCE Journal of Civil Engineering*, 100362. <https://doi.org/10.1016/j.kscej.2025.100362>
- Kumar, M., and Kumari, S. (2025). Causes of delays in road construction projects: A systematic review. *Journal of Financial Management of Property and Construction*, 30(2):256-294. <https://doi.org/10.1108/JFMPC-01-2023-0004>
- Liou, J.J.H., Chien, C.-W., Chang, F.-C., and Chuang, Y.-C. (2026). Integrating FMEA and HFACS to assess the risk to airport operations. *Journal of Air Transport Management*, 131:102902. <https://doi.org/10.1016/j.jairtraman.2025.102902>
- Nadeem, M., Jiskani, I.M., Urwat, M.S., Uddin, S., Akhtar, K., and Khokhar, N.H. (2023). Analysing delay factors in

- construction projects using Z-number approach: Insights from Pakistan. *Canadian Journal of Civil Engineering*, 50(12):966-983. <https://doi.org/10.1139/cjce-2022-0310>
- Pregina, K., and Kannan, M.R. (2024). Fuzzy-graphical evaluation and review technique for scheduling construction projects. *KSCE Journal of Civil Engineering*, 28(7):2573-2587. <https://doi.org/10.1007/s12205-024-0904-z>
- Rahim, M.S.A., Reniers, G., Yang, M., and Bajpai, S. (2024). Risk assessment methods for process safety, process security and resilience in the chemical process industry: A thorough literature review. *Journal of Loss Prevention in the Process Industries*, 88:105274. <https://doi.org/10.1016/j.jlp.2024.105274>
- Rani, H.A., Amin, J., Syuhada, R., Mubarak, M.H., and Aqsha, M.S. (2024). Enhancing supply chain management risk mitigation: A House of Risk methodology applied to brick manufacturing in Aceh Besar Regency. *Qeios*. <https://doi.org/10.32388/FSJF2F.2>
- Salah, B., Alnahhal, M., and Ali, M. (2023). Risk prioritization using a modified FMEA analysis in industry 4.0. *Journal of Engineering Research*, 11(4):460-468. <https://doi.org/10.1016/j.jer.2023.07.001>
- Shash, A.A., and Musabih, A.J. (2022). Delays in commercial buildings and their impact on stakeholders. *International Research Journal of Advanced Engineering and Science*, 7(4):94-102. <https://irjaes.com/wp-content/uploads/2022/10/IRJAES-V7N4P70Y22.pdf>
- Singh, H., Nielsen, M., and Greatrex, H. (2023). Causes, impacts, and mitigation strategies of urban pluvial floods in India: A systematic review. *International Journal of Disaster Risk Reduction*, 93:103751. <https://doi.org/10.1016/j.ijdrr.2023.103751>
- Tang, Y., Chen, Y., Hua, Y., and Fu, Y. (2020). Impacts of risk allocation on conflict negotiation costs in construction projects: Does managerial control matter? *International Journal of Project Management*, 38(3):188-199. <https://doi.org/10.1016/j.ijproman.2020.03.002>
- Ullah, S., Xiaopeng, D., Anbar, D.R., Amaechi, C.V., Oyetunji, A.K., Ashraf, M.W., and Siddiq, M. (2024). Risk identification techniques for international contracting projects by construction professionals using factor analysis. *Ain Shams Engineering Journal*, 15(4):102655. <https://doi.org/10.1016/j.asej.2024.102655>
- Won, J.W., Jung, W., Baek, S., and Han, S.H. (2024). Probability and impact perspectives on cost and schedule risks in international construction projects: An empirical investigation. *KSCE Journal of Civil Engineering*, 28(7):2600-2612. <https://doi.org/10.1007/s12205-024-2598-7>
- Xia, N., Guo, J., and Lin, Y.-H. (2021). Managing stakeholder attributes for risk mitigation: Evidence from construction project contractors. *International Journal of Managing Projects in Business*, 14(7):1605-1626. <https://doi.org/10.1108/IJMPB-11-2020-0345>
- Yang, J., Arditi, D., Lee, D.-E., and Mutis, I. (2022). Delay analysis selection model for a construction project. *KSCE Journal of Civil Engineering*, 26(12):4926-4941. <https://doi.org/10.1007/s12205-022-2394-1>