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Identification of Potential Hazards and Risks in Each Activity of SPAM (Drinking Water Supply System) Projects

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ABSTRACT
The Drinking Water Supply System (SPAM) is an important infrastructure designed to provide clean water to the community. However, the implementation of SPAM projects faces various challenges, especially in terms of work safety. Each stage of construction activities has potential hazards and risks that can affect the safety of workers, equipment, materials, and the environment/public. The high number of workplace accidents in the construction sector, including SPAM projects, demonstrates the need for comprehensive risk identification. This research aims to identify potential hazards and risks in each SPAM project activity. The research method used is qualitative analysis based on the potential hazards and risks that exist in the SPAM project. The data was analyzed to get the high risks that exist in the SPAM project. The results showed that potential hazards in the SPAM project include human error, non-standard machine conditions, exposure to hazardous materials, and unfavorable environmental conditions, such as bad weather, air and noise pollution. These risks can lead to worker injuries, material losses, project delays, and environmental impacts. The implications of this study highlight the critical need for comprehensive risk identification at every stage of a SPAM project to enhance workplace safety, minimize accidents, and ensure project sustainability.

Keywords: Construction Project, Occupational Safety, Potential Hazards, Risks, SPAM.

INTRODUCTION

Clean water is a fundamental human need essential for maintaining public health, economic productivity, and overall quality of life (Fatristya et al., 2025). Access to clean water is also recognized as a basic human right, as stated in the United Nations Sustainable Development Goals (SDGs), particularly in Goal 6, which aims to ensure availability and sustainable management of water and sanitation for all (Iskandar, 2020). However, despite significant global efforts, many regions still face challenges in providing adequate clean water supplies. The World Health Organization (WHO) and UNICEF (2021) reported that approximately 2.2 billion people worldwide lack access to safely managed drinking water services, and more than 4.2 billion people do not have access to safely managed sanitation facilities (Sopianti et al., 2024). These challenges are particularly acute in developing countries, where inadequate water infrastructure, rapid urbanization, and climate change exacerbate water scarcity and contamination risks.

To address these issues, the Drinking Water Supply System (SPAM) plays a crucial role in ensuring clean and safe water distribution to communities (Kasim, 2024). SPAM projects encompass multiple construction phases, including site preparation, excavation, pipe installation, the construction of water treatment facilities, and water distribution (Amilia Agustin & Dian Pramirasuci, 2022). These processes are vital for maintaining public health and ensuring sustainable development. However, the successful implementation of SPAM projects is often hindered by various challenges, particularly in the domain of occupational safety. The construction sector, including SPAM projects, is known for its high-risk work environment, where hazards and risks pose significant threats to workers, equipment, materials, and the surrounding environment.

Globally, the construction industry records one of the highest rates of workplace accidents. According to the International Labour Organization (ILO), construction-related accidents account for nearly 30% of all occupational fatalities worldwide (Agustian et al., 2020). Similarly, the Occupational Safety and Health Administration (OSHA) in the United States identifies falls, electrocution, struck-by objects, and caught-in/between incidents as the leading causes of fatalities in construction work, including water infrastructure projects. The failure to effectively manage hazards in SPAM projects can result in severe consequences, such as worker injuries, delays in project completion, financial losses, and long-term environmental degradation.

Specifically, in the context of SPAM projects, potential hazards include structural collapses during excavation, mechanical failures of heavy equipment, worker negligence, exposure to hazardous chemicals (such as chlorine and other water treatment substances), and unstable soil conditions that can lead to landslides. Weather-related hazards, including extreme heat and heavy rainfall, further exacerbate safety risks, increasing the likelihood of accidents on construction sites (Priyono et al., 2023). Despite the significant risks associated with these hazards, many construction projects still lack comprehensive risk assessment frameworks tailored to SPAM project requirements.

In Indonesia, work accidents in the construction sector remain a pressing issue. According to the Indonesian Ministry of Manpower, the construction industry consistently ranks among the top sectors with the highest workplace accident rates (Malik, 2018). In many SPAM projects, inadequate safety training, lack of adherence to standard operating procedures (SOPs), and insufficient supervision contribute to these accidents. The absence of proactive hazard identification and risk management strategies further amplifies the vulnerabilities faced by workers and stakeholders involved in SPAM construction activities.

Several previous studies have explored occupational safety risks in construction projects, highlighting the need for effective hazard identification and mitigation strategies. For instance, a study by (Nainggolan & Hendra, 2023) investigated construction safety hazards and emphasized the importance of proactive safety management approaches, including risk assessment and safety training. Their findings revealed that inadequate safety planning is one of the primary contributors to accidents in construction projects.

Another relevant study by (Sari et al., 2024) focused on risk assessment in water infrastructure projects, emphasizing the critical role of hazard identification in preventing project failures. The study outlined key risks such as poor soil stability, improper handling of hazardous materials, and inadequate equipment maintenance, all of which are pertinent to SPAM projects. However, while these studies provide valuable insights into construction safety, there is still a lack of research specifically addressing the unique hazards associated with SPAM projects.

Given the high accident rates in construction projects, there is an urgent need to improve safety measures in SPAM projects through comprehensive hazard identification and risk assessment. Effective safety management is not only essential for protecting workers but also for ensuring the timely and successful completion of clean water infrastructure projects. Delays caused by workplace accidents or safety violations can significantly impact public access to clean water, particularly in regions where SPAM projects serve as the primary source of safe drinking water.

Furthermore, regulatory bodies and construction firms must prioritize proactive safety planning to align with global best practices. Many SPAM projects in developing countries still lack structured risk management frameworks, relying instead on reactive measures that address hazards only after accidents occur (Prayoga et al., 2024). This reactive approach is costly, inefficient, and poses long-term sustainability challenges. By identifying potential hazards early in the project lifecycle, construction managers can implement targeted risk mitigation strategies, thereby reducing the likelihood of accidents and project failures.

This study contributes to the existing body of knowledge by focusing specifically on the unique hazards and risks present in SPAM projects, an area that has received limited research attention. Unlike general construction safety studies, this research provides a structured hazard identification framework tailored to SPAM construction activities, encompassing excavation, pipe installation, and water treatment facility construction.

Additionally, this study integrates both qualitative and risk-based assessments to provide a comprehensive understanding of potential hazards. By categorizing risks according to severity and likelihood, this research offers a practical approach to improving safety management in SPAM projects. The findings will serve as a reference for contractors, policymakers, and safety practitioners in optimizing risk mitigation strategies for clean water infrastructure projects.

Based on the above background, this study aims to identify potential hazards and risks at each stage of the SPAM project to improve work safety and reduce accidents and other negative impacts. The results of this study are expected to be a reference for project managers and contractors in managing risks, as well as for policy makers in formulating more specific work safety regulations for SPAM projects. In addition, this research makes an academic contribution to the development of occupational safety risk management studies and has a positive impact on the community by accelerating the provision of safe and sustainable access to clean water.

RESEARCH METHOD

Research Approach

This research uses a descriptive analysis method with a qualitative approach to identify potential hazards and risks in each SPAM (Drinking Water Supply System) project activity. This method aims to understand and explain the relationship between the identified risk factors and their influence on work safety.

Research Stages

Data Collection

a. Literature Study: Data was obtained from various supporting documents, such as government regulations, technical guidelines, and previous research on SPAM projects.
b. Expert Surveys and Interviews: Involving experts experienced in construction projects to identify relevant risks and hazards.
c. Archive Analysis: Historical data from work accident reports in previous SPAM projects were used to identify patterns of hazards and risks

Hazard and Risk Identification

a. Hazards are classified based on four main aspects: workers, equipment, materials, and environment/public. This approach follows applicable construction safety guidelines
b. Data is organized into risk categories based on their level of impact on safety, such as worker injury, machine damage, or environmental disruption.

Data Validation and Processing

a. Expert Validation: The identified hazards and risks were validated by five experts to ensure the relevance and accuracy of the results.
b. Pilot Survey Test: Conducted on 10 respondents to ensure that the research instrument (questionnaire) was well understood.
c. Questionnaire Distribution: The questionnaire was distributed to 35 respondents to measure the frequency and impact of each identified risk.

Data Analysis

a. Risk analysis was conducted by comparing the frequency and impact of hazards based on the scores given by respondents. The results were classified into high, medium and low risk categories.
b. Validity and reliability tests were conducted using the Cronbach's Alpha method to ensure consistency of the research results.

Analysis Framework

This research maps each project activity into a risk matrix that includes:

a. Identification of potential hazards by activity.

b. Assessment of the frequency and impact of risks to occupational safety.

RESULT AND DISCUSSION

Potential Hazards and Risks in SPAM Projects

The following is a classification of potential hazards and risks based on relevant aspects:

Table 1. Potential Hazards and Risks in SPAM Projects

1	Hazard Description	Risk Description
X1	Using materials containing hazardous substances without protective procedures	Long-term health problems, such as lung disease or cancer, respiratory problems
X2	Improperly stored materials at the work site	Fire or accident caused by falling materials
X3	Work is carried out in adverse weather conditions (rain, excessive heat)	Health risks for workers, including heat stress or hypothermia. Work delays and accidents
X4	Exposure to hazardous materials (dust, gas, etc.) Exposure to chemicals from concrete mixtures (cement, additives)	Respiratory illness or skin irritation due to exposure to harmful chemicals
X5	Waste from land clearing is not managed properly. Non-specific materials	Environmental pollution due to unmanaged construction waste
		Structural or functional failure
X6	Materials that are not securely stored or transported may fall over.	Injuries to workers below or to people around the site, such as punctures, falls, etc.
X7	Waste from construction activities that is disposed of carelessly	Ecosystem damage and potential lawsuits from communities
X8	Workers on roofs, scaffolding, or unprotected high places	Serious injuries such as broken bones, head trauma, or death
X9	Construction projects that destroy natural habitats of animals and plants	Loss of biodiversity and negative impacts on endangered species
X10	Workers are exposed to high noise levels during the course of work	Permanent hearing loss and stress
X11	Operating heavy machinery without training or without adequate protection	Loss of working ability or permanent disability
X12	Air pollution due to dust and noise pollution from heavy equipment	Decreased air quality that impacts the health of workers and the surrounding community
X13	Excessive workload and long working hours	Long-term health problems such as cancer, respiratory problems, or organ damage
X14	Using equipment that is not up to standard or connected to an unsafe power source	Fire, electric shock or fatal injury
X15	Mechanical failure of tools such as cranes or excavators. Use of tools without understanding instructions	Accidents involving workers and property damage

Source: Author's Process (2024)

Risk Validation

Expert risk validation aims to determine whether potential hazards and risks exist in the SPAM project. At this stage, discussions and validation were held with 5 experts for each variable. The following are the results of the recapitulation of the validation of these risk variables by experts. The results of expert risk validation can be seen as follows:

Variables	Hazard Description	Risk Description	Expert Validation					Conclusion
			P1	P2	P3	P4	P5	
X1	Using materials containing hazardous substances without protective procedures	Long-term health problems, such as lung disease or cancer, respiratory problems	✓	✓	✓	✓	✓	Yes
X2	Improperly stored materials at the work site	Fire or accident caused by falling materials	✓	✓	✓	✓	✓	Yes
X3	Work is carried out in adverse weather conditions (rain, excessive heat)	Health risks for workers, including heat stress or hypothermia. Work delays and accidents	✓	✓	✓	✓	✓	Yes
X4	Exposure to hazardous materials (dust, gas, etc.) Exposure to chemicals from concrete mixtures (cement, additives)	Respiratory illness or skin irritation due to exposure to harmful chemicals	✓	✓	✓	✓	✓	Yes
X5	Waste from land clearing is not managed properly. Non-specific materials	Environmental pollution due to unmanaged construction waste	✓	✓	✓	✓	✓	Yes
		Structural or functional failure	✓	✓	✓	✓	✓	Yes
X6	Materials that are not securely stored or transported may fall over.	Injuries to workers below or to people around the site, such as punctures, falls, etc.	✓	✓	✓	✓	✓	Yes
X7	Waste from construction activities that is disposed of carelessly	Ecosystem damage and potential lawsuits from communities	✓	✓	✓	✓	✓	Yes
X8	Workers on roofs, scaffolding, or unprotected high places	Serious injuries such as broken bones, head trauma, or death	✓	✓	✓	✓	✓	Yes
X9	Construction projects that destroy natural habitats of animals and plants	Loss of biodiversity and negative impacts on endangered species	✓	✓	✓	✓	✓	Yes
X10	Workers are exposed to high noise levels during the course of work	Permanent hearing loss and stress	✓	✓	✓	✓	✓	Yes
X11	Operating heavy machinery without training or without adequate protection	Loss of working ability or permanent disability	✓	✓	✓	✓	✓	Yes
X12	Air pollution due to dust and noise pollution from heavy equipment	Decreased air quality that impacts the health of workers and the surrounding community	✓	✓	✓	✓	✓	Yes
X13	Excessive workload and long working hours	Long-term health problems such as cancer, respiratory problems, or organ damage	✓	✓	✓	✓	✓	Yes
X14	Using equipment that is not up to standard or connected to an unsafe power source	Fire, electric shock or fatal injury	✓	✓	✓	✓	✓	Yes
X15	Mechanical failure of tools such as cranes or excavators. Use of tools without understanding instructions	Accidents involving workers and property damage	✓	✓	✓	✓	✓	Yes

Figure 1. Risk validation results

Source: Author's Process (2024)

Pilot Survey

The following is a recapitulation of the results of the respondent pilot survey, which aims to test the extent to which potential hazards and risks can be clearly understood by respondents.

This is done to ensure that the questionnaire is ready to be distributed to respondents in the actual assessment.

Variables	Hazard Description	Risk Description	Pilot Survey Respondents										Conclusion
			R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	
X1	Using materials containing hazardous substances without protective procedures	Long-term health problems, such as lung disease or cancer, respiratory problems	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X2	Improperly stored materials at the work site	Fire or accident caused by falling materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X3	Work is carried out in adverse weather conditions (rain, excessive heat)	Health risks for workers, including heat stress or hypothermia. Work delays and accidents	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X4	Exposure to hazardous materials (dust, gas, etc.) Exposure to chemicals from concrete mixtures (cement, additives)	Respiratory illness or skin irritation due to exposure to harmful chemicals	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X5	Waste from land clearing is not managed properly. Non-specific materials	Environmental pollution due to unmanaged construction waste	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
		Structural or functional failure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X6	Materials that are not securely stored or transported may fall over.	Injuries to workers below or to people around the site, such as punctures, falls, etc.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X7	Waste from construction activities that is disposed of carelessly	Ecosystem damage and potential lawsuits from communities	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X8	Workers on roofs, scaffolding, or unprotected high places	Serious injuries such as broken bones, head trauma, or death	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X9	Construction projects that destroy natural habitats of animals and plants	Loss of biodiversity and negative impacts on endangered species	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X10	Workers are exposed to high noise levels during the course of work	Permanent hearing loss and stress	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X11	Operating heavy machinery without training or without adequate protection	Loss of working ability or permanent disability	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X12	Air pollution due to dust and noise pollution from heavy equipment	Decreased air quality that impacts the health of workers and the surrounding community	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X13	Excessive workload and long working hours	Long-term health problems such as cancer, respiratory problems, or organ damage	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X14	Using equipment that is not up to standard or connected to an unsafe power source	Fire, electric shock or fatal injury	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand
X15	Mechanical failure of tools such as cranes or excavators. Use of tools without	Accidents involving workers and property damage	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Easy to understand

Figure 2. Risk Pilot Survey Results

Source: Author's Process (2024)

Based on the results of the pilot survey recapitulation above, it can be concluded that the questionnaire has been designed clearly and is easily understood by respondents, so that the next stage, namely the respondent survey, can be continued.

Validity and Reliability Test

The validity test is used to measure how precisely a measuring instrument is able to perform a function, while the reliability test is used to measure the consistency of the measuring instrument if the measurement is repeated. For the reliability test using the Cronbach's alpha method, where the research is said to be reliable if the alpha value is greater than the critical r value of product moment. The provisions of the reliability test with the Cronbach's alpha method are as follows:

a. Cronbach Alpha value ≤ 0.6 indicates that the research questionnaire is not reliable.
b. A Cronbach Alpha value ≥ 0.6 indicates that the research questionnaire is reliable.

As for being able to determine the level of reliability of the questionnaire by looking at the Cronbach's alpha value is as follows:

Table 2. Scoring for Cronbach's Alpha

Alpha	Reliability Level
0.00 to 0.20	Less Reliable
> 0.20 to 0.40	Somewhat Reliable
> 0.40 to 0.60	Moderately Reliable
> 0.60 to 0.80	Reliable
> 0.80 to 1.00	Very Reliable

Source: Ridwan (2006)

The following are the results of the reliability test on the respondent's questionnaire

Table 3. Reliability test results

Cronbach's Alpha	N of Items
0,924	15

Source: Author's Process (2024)

In the table above, it can be seen that the Cronbach's alpha value is 0.924, so it can be concluded that the questionnaire tested is reliable because the Cronbach's alpha value is greater than 0.8 and the reliability level of this study is very reliable because the Cronbach's alpha value is between> 0.80 to 1.00.

Furthermore, the validity test was carried out using the corrected item total correlation value with the test conditions as follows:

a. If the corrected item total correlation> r table, then the variable is valid
b. If the corrected item total correlation < r table, then the variable is invalid.

In this study, the r table is seen at the 95% confidence level or 5% significance for a 2-sided test with 35 respondents, so it has an r table worth 0.334. The following are the results of the validity test on 15 research variables.

Table 4. Validity test results

Variables	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Conclusion
X1	177,17	2960,205	0,742	0,916	Valid
X2	178,69	3207,516	0,454	0,925	Valid

Variables	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Conclusion
X3	178,14	3082,361	0,667	0,919	Valid
X4	177,26	2945,550	0,797	0,914	Valid
X5	179,26	3140,844	0,642	0,920	Valid
X6	177,57	3167,429	0,572	0,921	Valid
X7	178,54	2991,844	0,740	0,916	Valid
X8	176,29	3120,563	0,544	0,923	Valid
X9	180,37	2982,005	0,765	0,916	Valid
X10	179,49	3149,257	0,560	0,922	Valid
X11	177,00	3103,000	0,643	0,919	Valid
X12	178,77	3061,005	0,747	0,917	Valid
X13	178,11	3123,575	0,552	0,922	Valid
X14	175,63	3235,005	0,575	0,922	Valid
X15	176,51	3099,551	0,661	0,919	Valid

Source: Author's Process (2024)

By comparing the total correlation value obtained from SPSS processing results > from the r table (0.334), it can be concluded that all variables are valid, so that all variables can continue to be included in the risk level analysis.

Qualitative Risk Analysis

This stage of risk level analysis follows the Perform Qualitative Risk Analysis process listed in PMBOK 6th Edition as a guideline (Iribaram & Huda, 2019). Qualitative risk analysis is carried out using a probability and impact matrix. The following presents the frequency and impact scale values for each risk factor variable in accordance with the guidelines contained in PMBOK 6th Edition.

Qualitative risk analysis is obtained from the results of respondent surveys, namely the frequency and impact scales. Qualitative risk analysis in this study uses Perform Qualitative Risk Analysis in PMBOK 6th Edition as a guide. The following is the frequency and impact scale value for each risk factor variable in accordance with PMBOK 6th Edition:’

Table 5. Frequency scale values

Criteria	1	2	3	4	5
	Never	**Rarely**	**Sometimes**	**Often**	**Always**
Frequency	0.1	0.3	0.5	0.7	0.9

Source: Project Management Institute (2017)

Table 6. Impact scale values

Criteria	1	2	3	4	5
	Very low	**Low**	**Medium**	**High**	**Very high**
Impact	0.05	0.1	0.2	0.4	0.8

Source: Project Management Institute (2017)

Based on the table above, the frequency scale uses five categories, namely one to five in the order of never, rarely, sometimes, often, and always. While the impact scale has 5 categories, namely one to five in the order of very low, low, medium, high, and very high. The following are the results of the calculation of the average value of the frequency and impact of all risk variables.

Table 7. Mean value of risk frequency

Variables	Frequency Conversion Rate					Frequency Value	Average
	1	2	3	4	5		
	0,1	0,3	0,5	0,7	0,9		
X1	0,1	1,8	3,5	9,8	6,3	21,5	0,6143
X2	0,2	1,2	6	9,8	2,7	19,9	0,5686
X3	0,1	1,2	4,5	9,8	6,3	21,9	0,6257
X4	0,1	1,5	2	12,6	6,3	22,5	0,6429
X5	0,2	0,9	7	10,5	0,9	19,5	0,5571
X6	0	1,5	4	12,6	3,6	21,7	0,6200
X7	0,2	1,2	4	13,3	1,8	20,5	0,5857
X8	0,3	1,2	2,5	11,9	5,4	21,3	0,6086
X9	0,4	1,8	6,5	7	1,8	17,5	0,5000
X10	0,2	1,2	6	11,2	0,9	19,5	0,5571
X11	0,2	2,1	3	11,2	3,6	20,1	0,5743
X12	0	1,5	3	12,6	4,5	21,6	0,6171
X13	0,2	2,1	3	10,5	4,5	20,3	0,5800
X14	0	0,6	4	14	4,5	23,1	0,6600
X15	0,2	0,3	5,5	12,6	2,7	21,3	0,6086

Source: Author's Process (2024)

In the table above, the average value of risk frequency for each variable has been obtained, so the next step is to calculate the average value of risk impact, which is as follows:

Table 8. Average value of risk impact

Variables	Impact Conversion Rate					Impact Value	Average
	1	2	3	4	5		
	0,05	0,1	0,2	0,4	0,8		
X1	0,1	0,4	1,4	5,2	7,2	14,3	0,4086
X2	0,05	0,5	2	6,4	2,4	11,35	0,3243
X3	0,05	0,4	3,4	3,2	4	11,05	0,3157
X4	0,1	0,6	1,4	6	4	12,1	0,3457
X5	0,1	0,5	2	5,6	3,2	11,4	0,3257
X6	0	0,7	1,4	6,4	4	12,5	0,3571
X7	0,2	0,6	1	4,8	6,4	13	0,3714
X8	0	0,4	1	6	8,8	16,2	0,4629
X9	0,2	0,5	2,4	4	3,2	10,3	0,2943
X10	0,2	0,3	2,4	5,2	2,4	10,5	0,3000
X11	0	0,2	1,4	6,4	8	16	0,4571

Variables	Impact Conversion Rate					Impact Value	Average
	1	2	3	4	5		
	0,05	**0,1**	**0,2**	**0,4**	**0,8**		
X12	0,25	0,3	2,4	4,8	2,4	10,15	0,2900
X13	0,15	0,3	1,4	6,8	4	12,65	0,3614
X14	0	0	2,2	6	7,2	15,4	0,4400
X15	0	0,2	1,8	5,6	8	15,6	0,4457

Source: Author's Process (2024)

In the table above, the average risk impact value for each variable has been obtained. The next stage is the determination of the risk factor (FR) value, which is done by multiplying the average value of the frequency by the average value of the impact of each risk variable. The result of this multiplication will produce a risk rating for each variable. The following below is a frequency and impact matrix which is a reference in determining the value of the risk level.

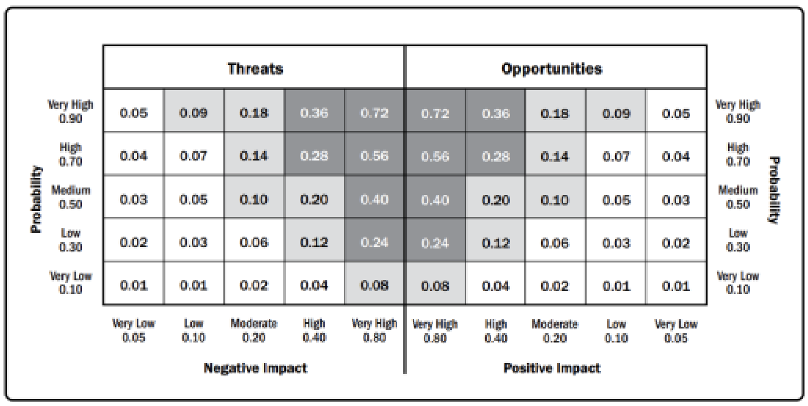

Figure 1. Frequency and impact matrix

Source: Project Management Institute (2017)

Based on the matrix above, the risk rating can be grouped with the following ranges:

a. Low risk : 0.01 – 0.07
b. Medium risk : 0.08 – 0.18
c. High risk : 0.24 – 0.72

Based on the risk rating grouping above, the following are the results of the risk value, risk rating, and risk level of each variable:

Table 9. Results of risk value, risk level and risk rating

Number	Variables	Average frequency score	Average impact score	Risk Value	Risk Level	Risk Rating
1	X1	0,6143	0,4086	0,2510	High	5
2	X2	0,5686	0,3243	0,1844	Medium	11
3	X3	0,6257	0,3157	0,1975	Medium	10
4	X4	0,6429	0,3457	0,2222	High	6

Number	Variables	Average frequency score	Average impact score	Risk Value	Risk Level	Risk Rating
5	X5	0,5571	0,3257	0,1815	Medium	12
6	X6	0,6200	0,3571	0,2214	High	7
7	X7	0,5857	0,3714	0,2176	High	8
8	X8	0,6086	0,4629	0,2817	High	2
9	X9	0,5000	0,2943	0,1471	Medium	15
10	X10	0,5571	0,3000	0,1671	Medium	14
11	X11	0,5743	0,4571	0,2625	High	4
12	X12	0,6171	0,2900	0,1790	Medium	13
13	X13	0,5800	0,3614	0,2096	High	9
14	X14	0,6600	0,4400	0,2904	High	1
15	X15	0,6086	0,4457	0,2712	High	3

Source: Author's Process (2024)

Based on the qualitative risk analysis, there are 9 risk variables with high risk levels in each work activity. The following is a recapitulation of risk variables with high ratings.

Table 10. List of Highest Risk Variables

Variables	Hazard Type	Hazard Description	Risk Type	Risk Description
X1	Material	Using materials containing hazardous substances without protective procedures	Workers	Long-term health problems, such as lung disease or cancer, respiratory problems
X4	Workers	Exposure to hazardous materials (dust, gas, etc.) Exposure to chemicals from concrete mixtures (cement, additives)	Workers	Respiratory illness or skin irritation due to exposure to harmful chemicals
X6	Material	Materials that are not securely stored or transported may fall over.	Workers	Injuries to workers below or to people around the site, such as punctures, falls, etc.
X7	Environment/ Public	Waste from construction activities that is disposed of carelessly	Environment/ Public	Ecosystem damage and potential lawsuits from communities
X8	Workers	Workers on roofs, scaffolding, or unprotected high places	Workers	Serious injuries such as broken bones, head trauma, or death
X11	Workers	Operating heavy machinery without training or without adequate protection	Workers	Loss of working ability or permanent disability

Variables	Hazard Type	Hazard Description	Risk Type	Risk Description
X13	Workers	Excessive workload and long working hours	Workers	Long-term health problems such as cancer, respiratory problems, or organ damage
X14	Equipment	Using equipment that is not up to standard or connected to an unsafe power source	Workers Equipment Environment/ Public	Fire, electric shock or fatal injury
X15	Equipment	Mechanical failure of tools such as cranes or excavators. Use of tools without understanding instructions	Workers Material Equipment	Accidents involving workers and property damage

Source: Author's Process (2024)

Discussion

Potential Hazards and Risks in SPAM Projects

Based on the findings, various potential hazards and risks have been identified in SPAM construction projects. These risks stem from several factors, including hazardous materials, improper handling and storage of materials, unsafe working conditions, environmental impacts, and deficiencies in worker safety protocols. The qualitative risk analysis results indicate that among the identified hazards, nine risks fall into the high-risk category, requiring immediate attention and mitigation strategies.

The risks associated with material hazards, such as exposure to hazardous substances without protective procedures (X1) and improper storage of materials (X6), are particularly concerning. Several studies support these findings, including research by (Pacheco-Torgal et al., 2012), which highlights that hazardous materials in construction projects contribute to long-term health issues, including respiratory problems and chemical burns. Similarly, Ahmed et al. (2021) found that improper handling of construction materials leads to serious workplace accidents, especially in water infrastructure projects. The risk of material-related accidents can be mitigated through improved hazard communication, the use of personal protective equipment (PPE), and better storage protocols.

Another significant hazard identified in SPAM projects relates to the working environment. Workers exposed to excessive workload and long working hours (X13) face long-term health problems, including chronic illnesses and decreased productivity. Research by (Malau & Ratnawati, 2024) confirms that excessive work hours and poor work-life balance contribute to mental and physical fatigue, increasing the likelihood of errors and workplace accidents. Furthermore, extreme environmental conditions, such as high temperatures, heavy rain, and poor air quality, exacerbate worker safety risks.

The findings also indicate that heavy machinery operation without adequate training (X11) and the use of non-standard equipment (X14) are among the highest-rated risks. This aligns with research conducted by (Putri & Lestari, 2023), which found that a lack of training and improper use of machinery contribute to a high percentage of accidents in construction projects. Operating cranes, excavators, or other heavy equipment without proper training increases the likelihood of mechanical failure and worker injuries. Studies by (Chinniah, 2015) emphasize that machine-related accidents can be significantly reduced by enforcing strict operational training and regular safety inspections of all equipment.

The environmental impact of SPAM construction activities is another critical aspect requiring attention. Risks such as improper waste management (X7) and destruction of natural habitats (X9) can lead to severe ecological consequences. The mismanagement of construction waste contributes to water contamination and soil degradation, affecting surrounding ecosystems and potentially leading to legal disputes (Ferronato & Torretta, 2019). Additionally, the destruction of habitats due to infrastructure development has been widely documented in global studies, indicating long-term biodiversity loss. Implementing strict environmental policies, conducting ecological impact assessments, and adopting sustainable construction practices are crucial to mitigating these risks.

Validation and Risk Assessment

The expert validation results confirm that the identified hazards and risks are significant and require structured mitigation measures. The reliability test using Cronbach's Alpha (0.924) further supports the consistency of the risk assessment methodology, indicating a high level of reliability in the data collection process. Similar approaches have been adopted in previous studies, such as those by (Fung et al., 2010), which emphasized the need for reliable risk assessment tools in construction projects. The qualitative risk analysis, based on PMBOK 6th Edition guidelines, provided structured categorization of risks, ensuring that mitigation efforts can be prioritized effectively. A key aspect of risk assessment in SPAM projects is determining the probability and impact of each risk. This approach ensures that high-risk variables such as exposure to hazardous materials (X1), unsafe working conditions (X8), and mechanical failures (X15) receive priority attention in safety planning.

CONCLUSION

The conclusion of this study shows that improving work safety management in SPAM projects through improved work safety training, standard operating procedures, routine equipment maintenance, proper material handling, and better work environment management. Effective project planning, hazard analysis, regulatory compliance, and stakeholder coordination are essential to minimize risk, prevent accidents, and ensure the continued success of SPAM projects. However, this study has limitations, including its reliance on literature and case reports, the absence of direct input from field workers, and a qualitative approach that may limit generalization. Future research should address these gaps by including field surveys, exploring specific project phases, using quantitative risk analysis, and leveraging advanced technologies such as drones and IoT-based monitoring for real-time hazard detection. Strengthening multi-stakeholder collaboration and expanding the scope of data will contribute to more comprehensive safety protocols, which in turn will increase the efficiency and sustainability of SPAM projects in providing clean water services.

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