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Risk Analysis of Occupational Safety and Health (OSH) Using the Hazard And Operability Study (HAZOP) Method for the Semani Drainage Project (Sentosa-Remaja-A. Yani)

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Abstract – The purpose of this research is to analyze the risk of accidents in the construction project of drainage in Semani (Sentosa-Remaja-A. Yani) with the aim of assessing the level of accident risk that occurs. Occupational Safety and Health is an obligation mandated by the Labor Law and the Minister of Manpower Regulation, so that the risk of accidents can be minimized. In the implementation of the drainage project in Semani (Sentosa-Remaja-A. Yani), the Occupational Safety and Health System (K3) has been applied properly, but accidents often result from the negligence of the workers themselves. Therefore, an appropriate approach is needed to identify accident risks. Hazard and Operability Study (HAZOP) is a method that can be applied to identify and analyze the risks of work accidents. The research results show that high-risk conditions account for 32%, medium-risk for 54%, and low-risk for 14%, so improvement recommendations are more focused on high and medium-risk conditions.

Keywords: Hazard and Operability Study, Construction Project, Work Risk

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1. Introduction

In the implementation of drainage construction projects, work accidents and health issues often occur, posing a significant concern for stakeholders and construction service companies. The impacts involve increased company budget expenditures. However, not all construction service companies prioritize Occupational Safety and Health (OSH), with some unwilling to allocate funds to address work accidents, especially in small-scale projects. The importance of OSH is acknowledged in the development of modern construction project implementation involving company management, labor, engineering equipment, and construction materials. Therefore, OSH issues should not be ignored [1] [2] [3].

To reduce or even eliminate hazards that can lead to accidents in the workplace, a risk management pattern is required, encompassing hazard mitigation, potential hazard analysis, risk assessment, risk control, as well as monitoring and evaluation. The goal is to achieve a zero-accident target. Accidents can be measured by the absence of accidents resulting in a loss of less than 48 working hours, such as accidents due to noise disturbances [4] [5] [6] [7]. Therefore, a socialization or training approach is needed in dealing with Occupational Safety and Health (OSH) issues [8] [9] [10].

In the process of identifying and analyzing potential hazards, the Hazard and Operability Study (HAZOP) method can be utilized. The aim is to identify possible hazards that may arise in the drainage project, with a focus on eliminating the main sources of accidents, such as being struck by concrete materials and being trapped [11].

Work accidents often occur at various stages of the drainage construction process, especially during excavation, casting, and precast installation. Working conditions in open areas also lead to many workers complaining of discomfort due to weather conditions and fatigue. Therefore, this research will apply the Hazard and Operability Study (HAZOP) method to the drainage construction project with the

2. Theoretical Basis

Work accidents are an unexpected and undesirable occurrence that disrupts activities and can cause harm to both people and property. There are two factors causing accidents, namely unsafe action (human factor) and unsafe condition (environmental factor). Unsafe action can be caused by various factors [12] [13] [14], among others :

1. Physical imbalance of the workforce includes body positions that can lead to fatigue, physical disabilities, temporary disabilities, as well as sensory sensitivity to the surrounding environment.
2. Educational shortcomings include lack of experience, misunderstanding of an instruction, insufficient skills, and errors in interpreting Standard Operating Procedures (SOP), which can ultimately lead to mistakes in the use of tools.
3. Performing tasks without the appropriate authority.
4. Performing work excessively or exceeding the established working hours.

2.1. Occupational Accident Risks in Construction Project

Risk identification is an effort to recognize or discover potential risks that may arise in activities carried out by the company [15]. The company manager is responsible for risk identification by investigating the possibilities of losses, evaluating the frequency and level of risk, selecting the most effective risk anticipation methods, and managing risk management programs. Information about risks can be obtained from internal documents such as financial reports, standard operating procedures, human resources documents, and other sources of information [16].

The process of risk identification needs to be conducted comprehensively to minimize the chances of undetected risks. In its implementation, risk identification can use various techniques, such as brainstorming (idea exchange), questionnaire (use of surveys or question-and-answer creation), industry benchmarking (industry comparison), scenario analysis (scenario analysis), risk assessment workshop (risk assessment workshop), incident investigation (incident investigation), auditing (audit), inspection (inspection), checklist (checklist compilation), and hazard and operability studies (hazard and operability studies) [17] [18] [19].

The management of this risk is carried out to minimize the potential impact of the risk as much as possible and enhance control over it. The following are strategies that can be applied :

1. Avoiding Rsik
   Avoiding risk is an important strategy to ensure that the company does not incur losses due to identified risks.
2. Preventing and Reducing Risks
   The next strategy is to prevent the occurrence of risks while reducing potential losses. For example, a construction company may decide to use new project equipment that is safer. Although this may require a higher budget expenditure, it is considered a better preventive measure against potential work accidents and a reduction of potential losses that might be greater if the equipment is not used.
3. Retaining Risk
   Risk retention refers to the estimation of risks internally, whether it includes the entire financial impact that a company may experience or only a portion. This risk retention strategy can be differentiated into two types, namely planned retention and unplanned retention.
4. Transferring Risk
   Risk transfer means transferring some or all of the potential risks to another party. This strategy is implemented through negotiations between construction companies and other parties, such as project owners, subcontractors, or suppliers. Typically, this risk transfer is carried out through provisions specified in contracts. For example, a company may enter into an agreement with a project owner, stating that if there are differences in on-site conditions during a project compared to what was agreed upon in the initial agreement, then an adjustment to the bid price can be made.
5. Insurance
   Obtaining insurance is one of the strategies often applied to manage risk. This approach is similar to risk transfer, where the insurance company is willing to bear the financial burden in the event of a loss.

2.2. Hazard and Operability Study (HAZOP)

Hazard and Operability Study (HAZOP) is a method used to conduct hazard analysis on a system [20] [21] [22]. This method applies qualitative techniques by using guide words to identify potential hazards. HAZOP is used to dissect each part of a process to detect deviations from the intended design and to understand their causes and consequences. The scheme is resolved using relevant guide words, and then it is adjusted based on severity values that reflect the rating of the severity itself

In order to assess criteria of severity, likelihood, and consequences, it is important to adhere to the standards established for measuring and evaluating these criteria. The criteria assessment standards in HAZOP align with the findings of researchers [23] [24] an be seen in Table 1 as follows.

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Table 1 Criteria Standard *Severity*

Severity	**Rating**	**Description**
Catastrophic	5	Fatality, permanent disability, serious, severe environmental damage, hazardous material leakage, very large financial loss, medical expenses > 50 million
Mayor	4	Workday loss, permanent/partial disability, moderate environmental damage, significant financial loss, medical expenses < 50 million
Moderat	3	Requires medical treatment, work disruption, fairly large financial loss, external assistance needed, medical expenses < 10 million
Minor	2	First aid treatment, minimal external assistance needed, moderate financial cost, medical expenses < 10 million
Negligible	1	No disruption to work processes, no injuries/wounds, small financial loss, medical expenses < 100 thousand

The following is the assessment standard for the Likehold HAZOP criteria, which can be seen in Table 2.

Table 2 *Likelihood* Criteria

Ranking	**Description**
Brand New Excellent	Risk rarely occurs, with an event frequency of less than four times in 10 years
Very Good/ Good Serviceable	Risk occurs 4-6 times in 10 years
Acceptable	Risk occurs between 6-8 times in 10 years
Below Standart/ Poor	Risk occurs 8-20 times in 10 years
Bad/ Unacceptable	Risk occurs 10 times in 10 years

The assessment standard for Consequence criteria in HAZOP can be seen in Table 3 as follows

Table 3 *Conseuquence* Criteria

Ranking	**Description**
Insignificant	The risk source (element/component/object in activities) has no impact at all; therefore, it is not significant to the continuity of activities, allowing the activities to proceed
Minor	The risk source (element/component/object in activities) has a minor impact, resulting in a small effect on the continuity of activities, allowing the activities to still proceed
Moderat	The risk source (element/component/object in activities) has a moderate impact, resulting in a moderate effect on the continuity of activities, allowing the activities to still proceed
Major	The risk source (element/component/object in activities) has a major impact, resulting in a significant effect on the continuity of activities, although the activities can still proceed, albeit not optimally
Catastrophic	The risk source (element/component/object in activities) has a very major impact, resulting in a highly significant effect on the continuity of activities, preventing the activities from proceeding

3. Research Method

This research employs both qualitative and quantitative research methods, with the research subject being project workers in the field who are involved in direct interactions and observe occupational health and safety systems [25] [26] [27] [28] [29]. The data processing process includes the following steps: a) understanding the sequence of drainage project work processes; b) identifying potential hazards from the beginning to the end of the project; c) observing deviations that could lead to work accidents; d) completing the HAZOP criteria on the worksheet; and e) ranking the identified potential hazards. Subsequently, this data is processed using Microsoft Excel. The research was conducted on Pemuda 1 Street, Temindung Permai Village, Sungai Pinang District, East Kalimantan Province, during the project

4. Result and Discussion

In relation to data processing, the step that needs to be taken is understanding the project workflow sequence. The following Table 4 shows the project workflow sequence for a 340-meter drainage channel :

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Table 4 The Drainage Project Activities in Semani (Sentosa-Remaja-A. Yani)

Code	Job	Job Type	Duration (Days)
1	A. Preparation Work	Mobilization and Demobilization	14
2		Occupational Health and Safety Management System Work	196
3		Utilities (PDAM, PLN, Telkom)	28
1	B. Construction Work	Excavation Waste (Equipment)	28
2		Earth Fill (Mechanical)	21
3		Concrete Demolition	28
4		Dismantling of Stone Pavement	28
5		Wood Demolition	28
6		Galam Wood Pile Base 12-15 cm, L = 3.75 m (Mechanical)	28
7		Concrete K - 250	161
8		Reinforcement	161
9		Formwork	161
10		Installation of PVC Pipes 3"	161

Based on the results of field observations (direct observation and interviews), it can be determined that the frequently occurring potential hazards are shown in Table 5 as follows

Table 5 Hazop Criteria

Identification Code	Potential Hazard
	A. Preparation Work
A1.1	Exposure to heavy rain
A1.2	Noise
A2.1	Direct exposure to sunlight
A3.1	Noise
	B. Construction Work
B1.1	Hit by heavy equipment
B1.2	Slip
B2.1	Buried under soil
B2.2	Eyes exposed to dust
B3.1	Hit by stone fragments
B3.2	Eyes exposed to dust
B4.1	Hit by stone fragments
B4.2	Eyes exposed to dust
B5.1	Hit by heavy equipment
B5.2	Hit by wood fragments
B6.1	Hit by wood
B6.2	Slip
B7.1	Hit by concrete material
B8.1	Hand caught in iron
B9.1	Hand hit by hammer
B9.2	Hand pierced by nail
B9.3	Hit by formwork material
B10.1	Hand trapped

The ranking of potential hazards is done using a worksheet, taking into account the likelihood and consequences. Then, a risk matrix is used to determine the priority of potential hazards that need attention for improvement. The ranking of potential hazards can be seen in Table 6 as follows

Table 6 The Ranking of Potential Hazards

Identification Code	Potential Accident Variables	Risk Of Accident Occurrence	*Severity Level*
	A. Preparation Work		
A1.1	Exposure to heavy rain	Headache/fever	2
A1.2	Noise	Disturbed ears	1
A2.1	Direct exposure to sunlight	Headache/fever	2
A3.1	Noise	Disturbed ears	1
	B. Construction Work		
B1.1	Hit by heavy equipment	Injury to the body	3
B1.2	Slip	Twisted ankle	3
B2.1	Buried under soil	Injury to the head	3
B2.2	Eyes exposed to dust	Eye irritation	2
B3.1	Hit by stone fragments	Injury to the body	3
B3.2	Eyes exposed to dust	Eye irritation	2
B4.1	Hit by stone fragments	Injury to the body	3
B4.2	Eyes exposed to dust	Eye irritation	2
B5.1	Hit by heavy equipment	Injury to the body	3
B5.2	Hit by wood fragments	Injury to the body	3
B6.1	Hit by wood	Injury to the body	3
B6.2	Slip	Twisted ankle	3
B7.1	Hit by concrete material	Injury to the body	3
B8.1	Hand caught in iron	Injury to the hand	2
B9.1	Hand hit by hammer	Injury to the hand	2
B9.2	Hand pierced by nail	Injury to the hand	2
B9.3	Hit by formwork material	Injury to the body	3
B10.1	Hand trapped	Injury to the hand	2

Based on Table 6, it can be determined that the severity level of work accidents is associated with the construction work variable, sub-variables with identification codes B1.1, B1.2, B2.1, B3.1, B4.1, B5.1, B5.2, B6.1, B6.2, B7.1, and B9.1. These include being hit by heavy equipment, slipping, being hit by wood and stone fragments, with the associated risk being injuries to the body and twisted ankles.

To determine the likelihood of work accidents on the drainage project, refer to Table 7 below

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Table 7 Likelihood (Probability) of Accidents Occurring

Identification Code	Potential Accident Variables	Risk Of Accident Occurrence	*Probability*
	A. Preparation Work		
A1.1	Exposure to heavy rain	Headache/fever	5
A1.2	Noise	Disturbed ears	2
A2.1	Direct exposure to sunlight	Headache/fever	2
A3.1	Noise	Disturbed ears	2
	B. Pekerjaan Konstruksi		
B1.1	Hit by heavy equipment	Injury to the body	3
B1.2	Slip	Twisted ankle	4
B2.1	Buried under soil	Injury to the head	4
B2.2	Eyes exposed to dust	Eye irritation	5
B3.1	Hit by stone fragments	Injury to the body	3
B3.2	Eyes exposed to dust	Eye irritation	5
B4.1	Hit by stone fragments	Injury to the body	3
B4.2	Eyes exposed to dust	Eye irritation	5
B5.1	Hit by heavy equipment	Injury to the body	3
B5.2	Hit by wood fragments	Injury to the body	3
B6.1	Hit by wood	Injury to the body	3
B6.2	Slip	Twisted ankle	4
B7.1	Hit by concrete material	Injury to the body	3
B8.1	Hand caught in iron	Injury to the hand	3
B9.1	Hand hit by hammer	Injury to the hand	3
B9.2	Hand pierced by nail	Injury to the hand	3
B9.3	Hit by formwork material	Injury to the body	3
B10.1	Hand trapped	Injury to the hand	3

Based on the above Table 7, it can be determined that the likelihood level of work accidents is associated with the preparation work variable, sub-variable with identification code A1.1 (exposure to heavy rain), B2.2, B3.2, and B4.2 (eye irritation due to dust), with a likelihood level value of 5. Therefore, the likelihood of accidents and occupational safety on the project can be minimized, and occupational health on the project can be improved.

Based on the data processing process, the final step is the creation of a risk matrix. This matrix serves as an evaluation of the severity and likelihood levels of a risk. The combination of these two aspects creates a recommendation view that can be generated by relevant parties in the project. Thus, efforts to reduce incidents and achieve zero work accidents can be realized, in line with the provisions of labor laws. The following is the risk matrix (See Table 8)

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Table 8 Risk Matrix Semani Drainage Project (Sentosa-Remaja-A. Yani)

Identification Code	Potential Accident Variables	Risk Of Accident Occurrence	*Severity*	*Probability*	Danger Level	Significan Risiko
		A. Preparation Work				
A1.1	Exposure to heavy rain	Headache/fever	2	5	10	*High Risk*
A1.2	Noise	Disturbed ears	1	2	2	*Low Risk*
A2.1	Direct exposure to sunlight	Headache/fever	2	2	4	*Low Risk*
A3.1	Noise	Disturbed ears	1	2	2	*Low Risk*
		B. Construction Work				
B1.1	Hit by heavy equipment	Injury to the body	3	3	9	*Medium Risk*
B1.2	Slip	Twisted ankle	3	4	12	*High Risk*
B2.1	Buried under soil	Injury to the head	3	4	12	*High Risk*
B2.2	Eyes exposed to dust	Eye irritation	2	5	10	*High Risk*
B3.1	Hit by stone fragments	Injury to the body	3	3	9	*Medium Risk*
B3.2	Eyes exposed to dust	Eye irritation	2	5	10	*High Risk*
B4.1	Hit by stone fragments	Injury to the body	3	3	9	*Medium Risk*
B4.2	Eyes exposed to dust	Eye irritation	2	5	10	*High Risk*
B5.1	Hit by heavy equipment	Injury to the body	3	3	9	*Medium Risk*
B5.2	Hit by wood fragments	Injury to the body	3	3	9	*Medium Risk*
B6.1	Hit by wood	Injury to the body	3	3	9	*Medium Risk*
B6.2	Slip	Twisted ankle	3	4	12	*High Risk*
B7.1	Hit by concrete material	Injury to the body	3	3	9	*Medium Risk*
B8.1	Hand caught in iron	Injury to the hand	2	3	6	*Medium Risk*
B9.1	Hand hit by hammer	Injury to the hand	2	3	6	*Medium Risk*
B9.2	Hand pierced by nail	Injury to the hand	2	3	6	*Medium Risk*
B9.3	Hit by formwork material	Injury to the body	3	3	9	*Medium Risk*
B10.1	Hand trapped	Injury to the hand	2	3	6	*Medium Risk*

Thus, it can be seen that the highest risk (high risk) is associated with the variables of potential exposure to heavy rain, slipping, being buried under soil, eyes exposed to dust, with risk level values of 10 and 12, indicated by the red color in the significant risk column. Medium risk (medium risk) is associated with construction work variables, specifically the potential risk of being hit by heavy equipment, being hit by stone fragments, being hit by wood fragments, being hit by concrete material, hand caught in iron, hand hit by hammer, hand pierced by nail, being hit by formwork material, and hand trapped, with risk level values of 6 and 9, indicated by the yellow color in the significant risk column. Low risk (low risk) in the initial work is associated with variables of noise and direct exposure to sunlight, with significant risk values of 2 and 4, indicated by the green color in the significant risk column

5. Conclusion

The significance of high risk has a percentage of 32%, and medium risk is 54%. This means that the potential or likelihood of losses due to work accidents with costs incurred between 40-50 million is 32% of the project budget. And the losses due to low-risk incidents (low risk) with a value of >10 million are 14% of the project budget

Recommendations from this research suggest focusing more on the significance of high risk and medium risk, which have values of 6-9 for medium risk and 10-12 for high risk. Thus, stakeholders can prepare personal protective equipment as needed as early as possible to minimize costs incurred due to work accidents..

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