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Work Accident Risk Analysis Using Hazard Analysis and Operability Study Method

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ABSTRAK

Salah satu pembangunan konstruksi yang ada di Indonesia yakni, proyek pembangunan Stadion Kabupaten Kediri. Pada setiap proyek konstruksi, sangat penting untuk dapat menerapkan Keselamatan dan Kesehatan Kerja menjadikannya sebagai perhatian utama. Hal ini guna mengantisipasi dampak negatif, seperti meningkatnya tingkat absensi, penurunan produktivitas, peningkatan biaya pengobatan, serta sebagai bentuk pengendalian segala risiko kecelakaan kerja yang ada di lingkungan kerja. Dampak ini memberikan kerugian baik bagi pekerja maupun perusahaan kontraktor. Oleh karena itu, harus dilakukan identifikasi, penilaian, serta analisis untuk dapat mengendalikan risiko kecelakaan kerja yang ada. Tujuan penelitian ini yakni untuk mengidentifikasi faktor risiko kecelakaan kerja, menilai risiko kecelakaan kerja, serta melakukan pengendalian terhadap risiko pada proyek pembangunan Stadion Kabupaten Kediri. Metode penelitian yang digunakan yakni metode Hazard Analysis and Operability Study (HAZOP). Hasil penelitian ini yakni terdapat 45 faktor risiko, 29 diantaranya valid, serta didapatkan hasil penilaian 2 risiko ekstrim, 3 risiko tinggi, 17 risiko sedang, dan 7 risiko rendah. Selain itu, sesuai dengan hierarki pengendalian risiko terdapat 3 jenis pengendalian risiko yang dapat diterapkan pada penelitian ini.

ABSTRACT

One of the construction developments in Indonesia is the Kediri Regency Stadium construction project. In every construction project, it is very important to implement Occupational Safety and Health making it a primary concern. This is to anticipate negative impacts, such as increasing absenteeism rates, decreasing productivity, increasing medical costs, as well as a form of controlling all risks of work accidents in the work environment. This impact causes losses for both workers and contractor companies. Therefore, identification, assessment and analysis must be carried out to be able to control the risk of work accidents. The aim of this research is to identify risk factors for work accidents, assess the risk of work accidents, and control risks in the Kediri Regency Stadium construction project. The research method used is the Hazard Analysis and Operability Study (HAZOP) method. The results of this research were 45 risk factors, 29 of which were valid, and the results obtained were 2 extreme risks, 3 high risks, 17 mederate risks and 7 low risks. Apart from that, according to the risk control hierarchy, there are 3 types of risk control that can be applied in this research.

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1. INTRODUCTION

Currently, the construction industry has become one of the main pillars in driving physical and economic development in various countries around the world [1]. The construction industry is considered one of the highest risk sectors in the world, with a much higher incidence rate, unlike most other industries [2]. Risks in construction projects are uncertain situations that can have a good or bad impact on the project objectives [3]. One risk that has a bad impact is the risk of work accidents. Every work environment has potential risks that can result in work-related accidents or illnesses. These accidents are undesirable, and can threaten anyone in the work environment [4]. If the workplace is not well organized and filled with risks, property damage, and high levels of absenteeism due to unavoidable illness, this can cause workers to experience lost income and decreased company productivity. Despite carefully organizing their business strategies, many entrepreneurs in various parts of the world still ignore important issues such as safety, physical well-being and working conditions [5]. Various types of hazards that exist in the construction sector have the potential to pose risks to worker safety. The risks of work accidents that are likely to occur on building projects include falling from a height, being pinched by materials/tools, fires due to welding, etc [6]. Including chemicals used during the construction process. These chemicals can contaminate the human body through direct contact with the skin, ingested through the mouth, or inhaled into the lungs [7].

Building construction generally carries a large risk of work accidents. The more complex the construction, the greater the impact on risk management. Relevant parties as holders of responsibility in the development process must make efforts to create guarantee programs that are able to reduce or even eliminate the probability of work accidents occurring. The party responsible for OHS risks is the HSE. HSE is responsible for running the project smoothly, the way is by carrying out HSE engineering. Today, HSE engineering has become a separate part of the design process, and has evolved into a method for predicting risk by using design simulation tools and scientific approaches to deploy human risk factors in manufacturing processes [8]. Work accidents can be avoided in many ways, such as increasing workers' OHS understanding, managing risks through the process of risk identification, risk assessment and controlling work accident risks, as well as carrying out risk mapping [9]. The way to increase workers' OHS understanding is by holding safety knowledge training, because having safety knowledge as a risk control program can reduce the frequency of work accidents in the workplace [10].

According to BPJS, the number of work accident cases in 2023 is 360,635 cases submitting JKK claims, this figure does not include companies that have not entered BPJS [11]. The number of work accidents in Indonesia is very large so efforts need to be made to reduce the rate of work accidents. Therefore, work accident risk analysis is needed to control the risk of work accidents. The aim of this research is to identify risk factors for work accidents, assess the risk of work accidents by applying the Hazard Analysis and Operability Study (HAZOP) method, and control risks in the Kediri Regency Stadium construction project. This HAZOP method regularly looks for various factors that can cause work accidents, determines the impact of risks, and recommends existing risk controls to eliminate or minimize potentially dangerous risks [12]

2. METHOD

The approach in this research is quantitative, presenting variables actually reinforced by numerical data originating from actual situations. The respondents for this research were 5 experts from the Kediri Regency Stadium construction project, 1 HSE Supervisor, 1 Safety Supervisor, 1 Paramedic, 1 Engineer, and 1 Technical Staff. In this research, the instruments used were Microsoft Excel and SPSS. The data in this research was obtained by distributing questionnaires to experts from Kediri Regency Stadium construction project. In this research, the method used was HAZOP. HAZOP, short for Hazard and Operability Study, is a risk analysis method used to assess and determine safety in a new or modified system, with the aim of identifying possible dangers or problems in its operability[13]. Risk assessment is carried out to assess the level of risk by taking into account the likelihood and severity of the consequences. Statistically, the level of risk can be represented as the result of multiplying the probability of work accident by the severity of work accident. Risk matrices, if defined correctly and used appropriately can be used to evaluate risk quantitatively[14]. The location of this research is the Kediri Regency Stadium construction project which is located at Semeru Street, Bulusari Village, Tarokan District, Kediri Regency. This research was carried out in March - April 2024.

3. RESULTS AND DISCUSSION

3.1. Risk Identification

In this research, validity testing was carried out with the aim of measuring the data obtained after the assessment, are valid data or not. This validity test uses Microsoft Excel and SPSS software as instruments. With an R table value of 0.8783 based on the total number of respondents. A variable is said to be valid if $R_{count} > R_{table}$ and conversely a variable can be said to be invalid if $R_{count} < R_{table}$. Valid data can be observed in table 1.

Table 1. Results of Work Accident Risk Identification and Validity Test

Code	Risk of Work Accidents	R Table	R Count	Description
A	**Excavation and Embankment Works**			
A1	Workers buried under excavation debris	0.8783	0.8355	Invalid
A2	Workers fall into excavations	0.8783	0.9801	Valid
A3	Worker hit by dump truck	0.8783	0.8201	Invalid
A4	Hit by an excavator	0.8783	0.9242	Valid
A5	Weight machines fell	0.8783	0.9242	Valid
A6	Worker electrocuted	0.8783	0.9801	Invalid
A7	Workers are trapped in the excavation area because there is no access/work ladder	0.8783	0.9242	Valid
A8	Workers are exposed to toxic gases	0.8783	0.6483	Invalid
A9	Material falls into the excavation	0.8783	0.8201	Invalid
B	**Piling Works**			
B1	Workers crushed by piles	0.8783	0.9572	Valid
B2	Fire due to pile welding	0.8783	0.9516	Valid
B3	Respiratory problems due to welding of stakes	0.8783	0.9516	Valid
B4	Hearing loss due to piling work	0.8783	0.9242	Valid
B5	Eye irritation due to connecting piles with welds	0.8783	0.7076	Invalid
B6	The worker was electrocuted	0.8783	0.8413	Invalid

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Code	Risk of Work Accidents	R Table	R Count	Description
B7	The piling tool sling broke	0.8783	0.8413	Invalid
B8	Workers fall into holes	0.8783	0.9516	Valid
B9	Workers are exposed to toxic gases	0.8783	0.6483	Invalid
B10	Workers hit by tools/materials	0.8783	0.7076	Invalid
C	**Casting Works**			
C1	Workers stuck in materials/tools	0.8783	0.3340	Invalid
C2	Workers are punctured, scratched, or cut by materials/tools	0.8783	0.9801	Valid
C3	Workers fall from height	0.8783	0.9540	Valid
C4	Workers are crushed by materials/tools	0.8783	0.9540	Valid
D	**Formwork Works**			
D1	Workers stuck in tools/materials	0.8783	0.9540	Valid
D2	Workers are hit by tools/materials	0.8783	0.9801	Valid
D3	Workers are punctured, scratched, or cut by materials/tools	0.8783	0.7353	Invalid
D4	Workers fall from height	0.8783	0.9540	Valid
D5	Hand tools error/wear out	0.8783	0.9801	Valid
E	**Foundry Works**			
E1	Workers are crushed by materials/tools	0.8783	0.9801	Valid
E2	Workers sprayed/doused with concrete	0.8783	0.8201	Invalid
E3	Workers fall from height	0.8783	0.9801	Valid
E4	Worker was electrocuted by a vibrator	0.8783	0.9262	Valid
E5	Irritation eye because of splash concrete	0.8783	0.9540	Valid
E6	Worker hit by weight machines	0.8783	0.8201	Invalid
F	**Material Lifting Works**			
F1	Tower crane collapsed	0.8783	0.9829	Valid
F2	Boom/jib broken	0.8783	0.9242	Valid
F3	Wire Sling Broken	0.8783	0.9242	Valid
F4	Worker hit by material	0.8783	0.9242	Valid
F5	Human error/ tools communication error	0.8783	0.9262	Valid
F6	Lifting load fall	0.8783	0.9262	Valid
F7	Weight machines rolled	0.8783	0.9242	Valid
G	**Additional Variable Risk**			
G1	Checklist before tool Work used	0.8783	0.4662	Invalid
G2	Weight machines collapsed	0.8783	0.9801	Valid
G3	Fatigue because of weather / temperature extreme	0.8783	0.6994	Invalid
G4	Chemical material allergy (cement, paint, etc.)	0.8783	0.9262	Valid

The data obtained with the assistance of Microsoft Excel and SPSS show the same result, namely that 29 out of 45 are valid variables. In the validity testing, the valid data is utilized as sub-risk factors which will subsequently be used for risk assessment.

Reliability test can be done after testing validity. The purpose of reliability testing is to determine whether the questionnaire is accurate and consistent in measuring the same variables. After obtaining valid data, the next step will be to proceed with reliability testing. In this research, SPSS is used as a tool for testing. A result of 0.993 was obtained, indicating that according to the Cronbach's Alpha coefficient values, the reliability degree is very high. Therefore, the conclusion drawn is that the data is reliable.

3.2. Risk Analysis and Risk Control

The risk analysis in this research is conducted using the Hazard Analysis and Operability Study (HAZOP) method. The risk level analysis of HAZOP can be seen in Table 2. In that matrix, the risk level can be determined by looking at the risk area according to the severity and likelihood of the risk. To obtain the risk value, multiply severity and likelihood.

Table 2. Analysis Matrix Risk According to *Standard AS/NZS 4360*

Likelihood	**Severity**				
	1	**2**	**3**	**4**	**5**
5	**H**	**H**	**E**	**E**	**E**
4	**M**	**H**	**H**	**E**	**E**
3	**L**	**M**	**H**	**E**	**E**
2	**L**	**L**	**M**	**H**	**E**
1	**L**	**L**	**M**	**H**	**H**

Description level risks :

E = Extreme Risk M = Moderate Risk

H = High Risk L = Low Risk

The results obtained from the risk assessment are not in integer values but rather decimal numbers, so a direct check using a risk matrix must be conducted. The results of risk impact (severity) and risk frequency (likelihood) are inputted into the risk matrix to determine the specific area of that risk. An example of the assessment results inputted into the risk matrix can be seen in Figure 1.

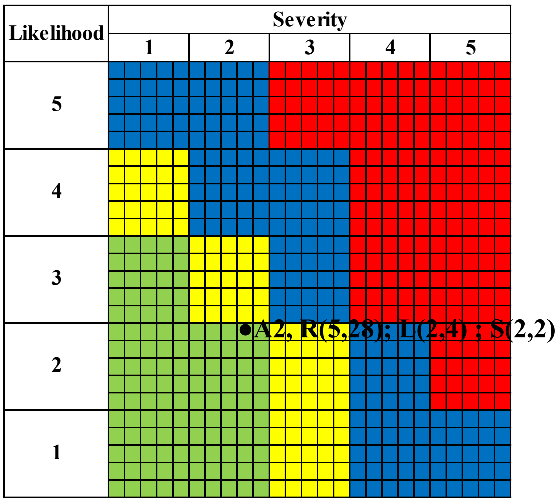

Figure 1. A2 Risk Matrix

Table 3. Risk Analysis and Risk Control

Code	Work Accident Risk	L	S	R		Risk Control	Recomandation Risk Control
A	**Excavation and Embankment Works**						
A2	Workers fall into excavations	2,4	2,2	5,3	L	Administration Control	Installation of barricades & safety signs.
A4	Being hit/struck by an excavator	2,0	3,2	6,4	M	Administration Control	Installation of barricades/safety cones/safety signs & signalman.
A5	Heavy machines fell	2,0	2,4	4,8	L	Administration Control	Implementation of work method statement, signalman, and toolbox meeting.
A7	Workers are trapped in the excavation area because there is no access/work ladder	2,0	2,4	4,8	L	Engineering Control	Installation of access ladder and landslide barrier wall.
B	**Piling Works**						
B1	Workers crushed by piles	2,4	3,2	7,7	M	Administration Control	Equipment inspection, installation barricade, safety sign, and toolbox meeting.
B2	Fire due to pile welding	2,2	2,8	6,2	M	Administration Control	Standby Portable Fire Extinguisher, firewatcher, and inspection of work equipment.
B3	Respiratory disturbances due to pile welding	2,2	2,8	6,2	M	PPE	The welder is using a pig-nose respirator/mask.
B4	Hearing impairment due to piling work	2,0	2,6	5,2	M	1. Administra-tion Control 2. PPE	Limiting the amount of time employees are exposed to noise and wearing earmuffs or earplugs.
B8	Workers fall into holes	2,2	2,6	5,7	M	Administration Control	Installation of barricades & safety signs.
C	**Casting Works**						

Code	Work Accident Risk	L	S	R		Risk Control	Recomandation Risk Control
C2	Workers are punctured, scratched, or cut by materials/tools	2,4	2,4	5,8	L	1. Administration Control 2. PPE	Wearing safety gloves (appropriate PPE), equipment inspection, Toolbox meeting.
C3	Workers fall from height	2,6	3,6	9,4	E	1. Administration Control 2. PPE	Providing height training to workers, using full-body harnesses, installing shark nets at the edge, and using appropriate footwear such as safety shoes/boots.
C4	Workers are crushed by materials/tools	2,6	3,2	8,3	H	PPE	Safety sign, barricade area with potential falling materials, avoiding SIMOPS (Simultaneous Operations).
D	**Formwork Works**						
D1	Workers stuck in tools/materials	2,6	2,8	7,3	H	1. Administration Control 2. PPE	Toolbox meeting, appropriate use of PPE, work performed by skilled personnel, and installation of safety signs.
D2	Workers are hit by tools/materials	2,4	2,8	6,7	M	Administration Control	Avoiding SIMOPS, safety sign, and installation of barricades.
D4	Workers fall from height	2,6	3,6	9,4	E	1. Administration Control 2. PPE	Full Body Harness, height training, DCU (Daily Check Up) monitoring.
D5	Hand tools error/wear out	2,4	2,0	4,8	L	1. Administration Control 2. PPE	Wearing safety gloves, safety goggles, protective clothing, and routine equipment inspection.
E	**Foundry Works**						
E1	Workers are crushed by materials/tools	2,4	2,4	5,8	L	Administration Control	Safety sign, barricade area, avoiding SIMOPS.

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Code	Work Accident Risk	L	S	R		Risk Control	Recomandation Risk Control
E3	Workers fall from height	2,4	2,6	6,2	M	1. Administration Control 2. PPE	Full Body Harness, height training, DCU (Daily Check Up) monitoring.
E4	Worker was electrocuted by a vibrator	2,2	3,0	6,6	M	1. Administration Control 2. PPE	Repairing or replacing damaged equipment (equipment inspection), not working during rain, and wearing PPE such as safety gloves.
E5	Eye irritation due to concrete splashes	2,6	2,6	6,8	M	PPE	Wearing PPE such as safety goggles/glasses according to standards and working carefully.
F	**Material Lifting Works**						
F1	Tower crane collapsed	2,0	3,0	6,0	M	Administration Control	Ensuring regular and thorough equipment checks (inspections) and ensuring that loads do not exceed lifting capacity (engineering calculations).
F2	Boom/jib broken	2,0	2,8	5,6	M	Administration Control	Ensuring to conduct regular and meticulous equipment inspections and ensuring that loads do not exceed lifting capacity (engineering calculations).
F3	Wire Sling Broken	2,0	3,0	6,0	M	Administration Control	Ensuring to always conduct regular and meticulous equipment inspections, perform equipment testing, and barricade the lifting area.
F4	Worker hit by material	2,0	3,0	6,0	M	Administration Control	Avoiding SIMOPS (Simultaneous Operations), safety signage, and barricading the work area.
F5	Human error/ communication tools error	2,2	2,4	5,3	L	Administration Control	Toolbox meeting, work performed by certified riggers & operators, inspection communication tools.

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Code	Work Accident Risk	L	S	R		Risk Control	Recomandation Risk Control
F6	Lifting load fall	2,2	3,2	7,0	M	Administration Control	Toolbox meeting, work performed by certified riggers & operators, barricading the lifting area, inspection of heavy machines.
F7	Heavy machines rolled	2,0	2,8	5,6	M	Administration Control	Outrigger crane must be fully extended, work area barricaded, implementation of lifting plan.
G	**Additional Variable Risk**						
G2	Heavy machines collapsed	2,4	2,6	6,2	M	Administration Control	Heavy machines base plate, lifting plan, work method statement, toolbox meeting.
G4	Chemical material allergy (cement, paint, etc.)	2,2	2,6	5,7	M	PPE	Wearing PPE according to standards, handling plan for hazardous and toxic materials, MSDS dissemination containing material properties, types of hazards, and special emergency actions.

From the risk assessment above, the risk groups obtained are as follows:

1. The extreme risk in this study is workers fall from height (C3) and workers fall from height (D4).
2. The high risks in this study are workers are crushed by materials/tools (C4), workers stuck in tools/materials (D1), and eye irritation due to concrete splashes (E5).
3. The moderate risks in this study are being hit/struck by an excavator (A4), workers crushed by piles (B1), fire due to pile welding (B2), respiratory disturbances due to pile welding (B3), hearing impairment due to pile driving (B4), workers fall into holes (B8), workers are hit by tools/materials (D2), workers fall from heights (E3), worker was electrocuted by a vibrator (E4), tower crane collapse (F1), wire sling broken (F3), worker hit by material (F4), lifting load fall (F6), heavy machines rolled (F7), heavy machines collapsed (G2), and chemical material allergies (cement, paint, etc.) (G4).
4. The low risks in this study are workers fall into excavations (A2), heavy machines fell (A5), workers are trapped in the excavation area because there is no access/work ladder (A7), workers are punctured, scratched, or cut by materials/tools (C2), hand tools error/wear out (D5), workers are crushed by materials/tools (E1), and human error/communication tools error (F5).

Out of 29 hazard risks, there are 4 risk groups, consisting of 2 extreme risks, 3 high risks, 17 moderate risks, and 7 low risks. Each risk has been provided with risk control recommendations.

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Risk control is a way to eliminate or reduce the potential hazards so that they do not pose a risk to workers [15]. In risk control, there are 5 hierarchical methods starting from Elimination, Substitution, Engineering Controls, Administration Controls, and Personal Protective Equipment (PPE). In this study, there are three types of risk control that can be applied. These controls are Engineering Controls, Administrative Controls, and Personal Protective Equipment (PPE).

4. CONCLUTION AND RECOMMENDATIONS

1. Based on the research results, there are 45 work accident risk. Among these accident risk variables, 29 of them are valid and reliable.
2. In the risk assessment of work accidents on the construction project of Kediri District Stadium, there are 2 risks categorized as extreme risk, 3 risks categorized as High Risk, 17 risks categorized as Moderate Risk, and 7 risks categorized as Low Risk.
3. In the construction project of Kediri District Stadium, there are 3 types of risk control that can be applied. These controls are engineering controls, administrative controls, and Personal Protective Equipment (PPE).

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