Original Research Article

Risk Analysis of Occupational Hazards Using HIRADC Approach in The Implementation Of Occupational Safety and Health Management System

ABSTRACT

The high construction intensity can increase the risk of construction work accidents if not supported by good work method planning, risk management, and supervision. Indonesian National Social Security Agency for Employment (BPJS) noted that in 2017 the number of work accidents reported reached 123,041 cases, while throughout 2018, it reached 173,105 cases. Furthermore, in 2019 it was 114,000 cases and experienced an increase in claims by 55.2% to 177,000 cases in 2020. Then, from January to September 2021, there were 82,000 work accidents and 179 occupational diseases, 65 percent of which were caused by Covid-19 [1]. One approach to risk management is Hazard Identification, Risk Assessment, and Determining Control (HIRADC) to identify hazards, assess whether the risks on the job fall into the category of danger or very dangerous, and control the hazards that will happen. The study's objectives include identifying jobs at risk of occupational accidents during construction, analyzing the level of risk of occupational accidents to implement the occupational safety and health management system during construction, and providing control measures to reduce the risk of accidents. The results of the study stated that from a total of 49 hazard identification in the project construction work, there are 142 accident risks, with a percentage of 14% of the risks included in the high-level risk criteria, 86% included in the medium-level risk criteria, and there are no risks in the low-level risk criteria.

Keywords: Work Accident, Accident Identification, Severity Index

1. INTRODUCTION

The increases in population caused by significant urbanization in Bogor City projects several surrounding cities as buffer cities. One of the buffer districts of Bogor City is Cibinong. Therefore, the development of facilities and infrastructure in Cibinong in the last five years has been very rapid. The high intensity of development can increase the potential risk of construction work accidents if not supported by good work method planning, risk management, and supervision. Indonesian National Social Security Agency for Employment (BPJS) noted that in 2017 the number of work accidents reported reached 123,041 cases, while throughout 2018, it reached 173,105 cases. Furthermore, in 2019 it was 114,000 cases and experienced an increase in claims by 55.2% to 177,000 cases in 2020. Then, from January to September 2021, there were 82,000 work accidents and 179 occupational diseases, 65 percent of which were caused by Covid-19 [1]. Construction sites are dangerous places where injury or death or illness can cause to workers. These can happen due to electrocution, falling from height, injuries from tools, equipment and machines; being hit by moving construction vehicles, injuries from manual handling operations, illness due to hazardous substance such as dust, chemicals, etc [2].

There are 82 risks originating from 29 construction jobs, with the percentage of the risk level being 44% of the risks at priority level 1, which causes the impact of death and permanent injury, priority level 2, which causes severe but non-permanent injury. As much as 24% of the risks fall into the moderate category, and priority level 3 as much as 32% of the risks fall into the low and mild category [3]. The impact caused from working accidents is relatively significant, besides deaths and workers' life quality decline, working accidents in construction projects causes project delays, increasing product cost, medical burden, and other negative consequences [4]. Based on the data, an improvement effort with risk management from the identification stage, hazard risk assessment, risk control, and the implementation stage of the construction safety management system. One approach to risk management is Hazard Identification, Risk Assessment, and Determining Control (HIRADC) as an effort to identify hazards, assess whether the risks on the job fall into the category of danger or very dangerous, and control the hazards that will occur. The purposes of this research include identifying jobs at risk of occupational accidents during construction, analyzing the level of risk of occupational accidents to implement occupational safety and health management systems during construction, and determining control to reduce the risk of accidents.

2. LITERATURE REVIEW AND RESEARCH

2.1 Construction Accident

The definition of a construction accident according to the Regulation of the Minister of Public Works and Housing is an event due to negligence at the construction work stage due to non-fulfillment of security, safety, health, and sustainability standards, which results in loss of property, work time, death, permanent disability, and environmental damage [5].

2.2 Risk Management

Risk management is managing risks starting from identifying hazards, assessing risk levels, and controlling risks [6]. Risk management can be defined as the process of taking calculated risks, reduces the likelihood that a loss will occur and minimizes the scale of the loss should it occur. The main objective of risk management process is to reduce the risk effect on the project objectives and thus improve decision-making [7].

2.2.1 HIRADC (Hazard Identification, Risk Assesment, and Determining Control)

HIRADC (Hazard Identification, Risk Assessment, and Determining Control) is a work program in which there is a process of recognizing hazards in a job, making hazard identification and the value of the risk of these hazards and then controlling the risks and hazards that have been identified [8]. Construction safety risk assessment is the calculation of the amount of potential based on the possibility of events that have an impact on the loss of construction, human life, public safety, and the environment that can arise from certain sources of danger, occurring in construction work [1]. Risk parameters are probability and severity. Probability is defined as the likelihood of a risk occurring due to the presence of a hazard. It is also the chance of an accident or event occurring. Severity is defined as the most likely outcome of a potential accident, including injuries and property damage [9]. Severity Index (SI) shows an index of how much the level of risk factors influences the performance of the people involved [10]. The severity index (SI) is calculated by Equation 1 [11].

$$SI = \frac{\sum_{i=1}^{5} a_i . x_i}{5 \sum_{1=0}^{5} x_i} \text{ x } 100\% \qquad (1)$$

with:

a_i = constant index

x_i = frequency of respondents

I = 1, 2, 3, 4, 5,...,n

x_1, x_2, x_3, x4, x_5 are the respondent frequency responses

a_1 = 1, a_2 = 2, a_3 = 3, a_4 = 4, a_5 = 5

x_1 = respondent frequency "Very Rarely" then $a_1 = 1$
x_2 = frequency of respondents "Rarely," then $a_2 = 2$
x_3 = frequency of respondents "Moderately" then $a_3 = 3$
x_4 = frequency of respondents "Often" then $a_4 = 4$
x_5 = frequency of respondents "Very Often" then $a_5 = 5$

The severity index results will be processed into a classification of risk level points according to the indicators in Table 1[12] and Table 2[12]. Furthermore, the results are plotted in the risk matrix in Figure 1[5] using the probability and impact multiplication formula.

Table 1. Severity index for frequency

No	Category	SI Index	Value
1	Very often (SS)	87.5% ≤ SI ≤ 100%	5
2	Often (S)	62.5% ≤ SI ≤ 87.5%	4
3	Moderate (C)	37.5% ≤ SI ≤ 62.5%	3
4	Rare (J)	12.5% ≤ SI ≤ 37.5%	2
5	Very Rare (SJ)	0.00% ≤ SI ≤ 12.5%	1

Table 2. Severity index for impacts

No	Category	SI Index	Value
1	Very Large (SB)	87.5% ≤ SI ≤ 100%	5
2	Large (B)	62.5% ≤ SI ≤ 87.5%	4
3	Medium (S)	37.5% ≤ SI ≤ 62.5%	3
4	Small (K)	12.5% ≤ SI ≤ 37.5%	2
5	Very Small (SK)	0.00% ≤ SI ≤ 12.5%	1

		Impacts				
		1	2	3	4	5
Frequency	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Figure 1. Impact and frequency matrix

2.3 Validity and Reliability Test

The validity test is an effort to ensure the level of validity in the design of statements and questionnaire questions submitted by researchers to respondents. The validity test is carried out by comparing the value of the r_{count} with the r_{table}[13]. If the value of the r_{count} is more than the level of significance, then the instrument is declared valid, but if the value of the r_{count} is less than the level of significance, then the instrument is declared invalid. The level of significant reliability is less than 5% can be seen in Table 3 [13].

Table 3. Significance reabillity

N	The Level of Significance		N	The Level of Significance	
	5%	1%		5%	1%
3	0.997	0.999	18	0.468	0.590
4	0.950	0.990	19	0.456	0.575
5	0.878	0.959	20	0.444	0.561
6	0.811	0.917	21	0.433	0.549
7	0.754	0.874	22	0.432	0.537
8	0.707	0.834	23	0.413	0.526
9	0.666	0.798	24	0.404	0.515
10	0.632	0.765	25	0.396	0.505

11	0.602	0.735	26	0.388	0.496
12	0.576	0.708	27	0.381	0.487
13	0.553	0.684	28	0.374	0.478
14	0.532	0.661	29	0.367	0.470
15	0.514	0.641	30	0.361	0.463
16	0.497	0.623	31	0.355	0.456
17	0.482	0.606	32	0.349	0.449

The reliability test aims to test the level of consistency of the resulting instrument variable and whether it is reliable [14]. The test is carried out by comparing Cronbach's Alpha value with the significant level used as shown in Table 4 [14].

Table 4. Cronbach's alpha coefficient levels

Cronbach’s Alpha	Reliability Levels
0.00 s/d 0.20	Unreliable
0.20 s/d 0.40	Not Reliable Enough
0.40 s/d 0.60	Moderate Reliable
0.60 s/d 0.80	Reliable
0.80 s/d 1.00	Very Reliable

2.4 Determining Control

Determining control is an effort to eliminate or reduce risks and increase opportunities identified and assessed based on the construction safety risk assessment results.Determining control must implement an integrated risk control analysis of the results of hazard identification, namely by controlling based on the following [5]:

1). Engineering control;
2). Administrative control;
3). Human behavior aspects; and
4). Aspects of change and dynamics of construction work.

3. RESULTS AND DISCUSSION

3.1 Risk Identification

Risk identification was carried out based on literature studies and work methods used for the project. In addition, risk identification was also carried out in the form of visual observations in the field during the construction. The observations in the field resulted in various kinds of hazard identification, as seen in **Figure 2**.

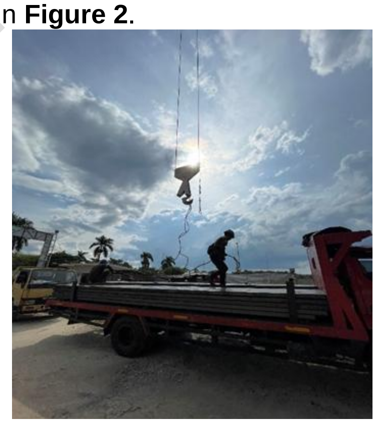

Figure 2. Material mobilization from stockyard to work site

Figure 2. show the activity of materials mobilization from the stockyard to the work site using vehicles and cranes if necessary. The activity has various kinds of hazard identification that can cause work accidents. An example of hazard identification is a skidding mobilization

vehicle with various risks of work accidents, such as vehicles falling on workers, vehicles hitting workers, and workers being injured.

3.1.1 Hazard Identification in Structural Work

Table 5. Recapitulation hazard identification in structural work

No	JobDescription	HazardIdentification	Risk
A	**Structural Work**		
1	**Column, Beam and Plate**		
1.1	Mobilization ofmaterials fromstockyard towork site	Material mobilization	Worker tripped
			Worker hit by a tool
			Worker hit
		Workers do notuse PPE	Workers fall from tools or materials
		Mobilizationvehicle derailed	Vehicle hits worker
			Bumping into workers
			Worker injured
1.2	Rebar fabrication	Usingrebar cutter	Injured worker
			Eye irritation
			Worker's hearing is impaired
		Rebar mobilization	Worker impaled by iron
1.3	Concrete reinforcing bars	Rebar mobilization	Worker hit
			Worker crushed by rebar
			Worker impaled by rebar
		Rebar installation	Worker punctured by tool/material
			Workers tripped over materials
			Falling from a height
			Pinched by wire cutters
1.4	Formworkfabrication	Panel mobilization	Worker hit
			Worker crushed by a panel
		Panel installation	Worker crushed by a panel
			Worker pinched by iron bracing
			Worker hit by iron bracing
			Worker punctured by tool/material
1.5	Concrete mixing	Concrete mixer lifting	Worker hit by mixer
			Worker crushed by mixer
			Worker tripped
			Falling from a height

No	JobDescription	HazardIdentification	Risk
		Use of a vibrator	Worker electrocuted
			Falling from a height
2	**Staircase**		
2.1	Scaffolding work	Scaffolding installation	Worker hit by scaffolding
			Worker hit by tools/materials
			Falling from a height
			Scaffolding collapse
2.2	Formwork fabrication	Panel installation	Worker crushed by a panel
			Worker pinched by a panel
2.2	Formwork fabrication	Panel installation	Falling from a height
			Worker punctured by tool/material
2.3	Concrete mixing	Concrete mixer lifting	Worker hit
			Worker crushed by mixer
			Worker tripped
			Falling from a height
		Using vibrator	Worker electrocuted
			Falling from a height

3.1.2 Hazard Identification in Architectural Work

Table 6. Recapitulation hazard identification in architectural work

No	Job Description	Hazard Identification	Risk
B	**Architectural Work**		
1	**Brick Installation**		
1.1	Scaffolding work	Installation of scaffolding	Worker hit by scaffolding
			Worker hit by tools/materials
			Falling from a height
			Scaffolding collapse
1.2	Practical column work	Practical installation of column cuttings	Eye irritation from dust
			Worker's hearing is impaired
		Practical column fixing	Worker punctured by tool/material
			Pinched by wire cutters
		Formwork installation	Worker crushed by a panel
			Worker pinched by a panel
			Worker punctured by tool/material
		Pratical column casting	Workers pouring concrete
			Falling on formwork
			Electrocution of vibrator
1.3	Brick installation	Brick installation	Brick fall
			Injured by tools/materials

No	Job Description	Hazard Identification	Risk
			Eye irritation from dust
			Impaired hearing
			Falling from a height
2	**Plastering Work**		
2.1	Plastering work	Plastering installation	Eye irritation
			Skin irritation
			Injured by tools
			Falling from a height
		Using bar jidar	Bar jidar fall
			Scratched by jidar
			Pierced by jidar
3	**Ceiling Installation**		
3.1	Preparation work	Scaffolding installation	Worker hit by scaffolding
			Worker hit by tools/materials
			Falling from a height
			Scaffolding collapse
3.2	Ceiling work	Using drill	Eye irritation
			Electrocution
			Equipment fall
			Impaired hearing
		Installation of ceiling frame	Falling on the ceiling frame
			Injured by tools/materials
			Falling from a height
		Ceiling installation	Falling tools/materials
			Falling on the ceiling
			Injured by tools
			Falling from a height
4	**Door and Window Installation**		
4.1	Preparation work	Window and door mobilization	Worker hit
			Worker hit by door/window
			Workers tripped over materials
			Injured by tools/materials
			Pinched worker
4.2	Door and window installation	Installation of doors and windows	Worker hit by door/window
			Worker wedged in door/window
		Using drill	Electrocution
			Worker's hearing is impaired
		Finishing	Skin irritation
			Impaired breathing
5	**Painting Work**		
5.1	Painting Work	Material mobilization	Worker tripped
			Worker hit by material
		Wall surface cleaning	Eye irritation from dust
			Injured by tools
			Falling from a height

No	Job Description	Hazard Identification	Risk
		Painting work	Impaired breathing
			Injured by tools
			Falling from a height

3.1.3 Hazard Identification in MEP Work

Table 7. Recapitulation hazard identification in MEP

No	Job Description	Hazard Identification	Risk
C	**Plumbing Installation**		
1	**Pipe Installation**		
1.1	Pipe installation	Material mobilization	Worker tripped
			Worker hit by material
		Using drill	Electrocution
			Worker's hearing is impaired
			Eye irritation
			Falling from a height
		Pipe installation	Falling tools/materials
			Injured by tools
			Impaired hearing
			Falling from a height
2	**Hydrant Installation**		
2.1	Hydrant installation	Material mobilization	Worker tripped
			Falling on tools/materials
		Hydrant installation	Impaired hearing
			Injured by tools/materials
			Electrocution
D	**Mechanical Work**		
1	**Lift Installation**		
1.1	Preparation work	Material mobilization	Worker hit
			Material fallout
			Worker tripped
			Injured by tools/materials
			Impaired hearing
			Exposed to lift debris
1.2	Lift installation	Chainblock broken	The lift fell down
			Causes vibration
			Exposed to lift debris
		Electrical installation	Worker tripped
			Electrocution
			Injured by tools
E	**Electrical Work**		
1	**Panel and Feeder Cable Installation**		
1.1	Panel work and feeder cables	Electrical installation	Worker electrocuted
			Workers burned
			Injured by tools
2	**Power Lighting Installation**		
2.1	Cable installation	Ladder mobilization	Worker tripped

No	Job Description	Hazard Identification	Risk
			Worker falls down the ladder
		Using drill	Electrocution
			Worker's hearing is impaired
			Eye irritation from dust
			Falling from a height
		Electrical installation	Electrocution
			Workers suffer burns

3.2 Severity Index

The severity index calculation determines significant risks in terms of probability and impact. The severity index value is generated using the Equation 1 formula in the form of a percentage (%).

3.2.1 Severity Index Levels in Structural Work

Table 8. Recapitulation of severity index levels in structural work

Severity Index Frequency	Severity Index Impact	Risk Level
52.26	65	Medium
62	56	Medium
54.26	60.10	Medium
65	44.42	Medium
69	71	High
67	63.10	High
64	62.12	Medium
63	65	High
42.42	59	Medium
44.42	64	Medium
46.38	63	Medium
52.25	61.10	Medium
57.20	40.42	Medium
56.25	65.00	Medium
47.37	65.00	Medium
54.26	67	Medium
59.16	60.16	Medium
55.21	63	Medium
63.11	67	High
49.32	66	Medium
57.21	68	Medium
50.32	58	Medium
49.32	65	Medium
44.42	52	Medium
65	47.37	Medium
57	57.21	Medium
66	50	Medium
61	52.32	Medium
59.16	67	Medium
66	52.32	Medium

Severity Index Frequency	Severity Index Impact	Risk Level
64.05	57	Medium
50.32	64	Medium
64	67	High
69	63	High
67	70	High
69.05	52	Medium
67	51.32	Medium
44.45	63	Medium
65.11	69	High
69.00	71	High
58.21	66	Medium
47.37	56.25	Medium
39.47	64.05	Medium
61.15	48.38	Medium

3.2.2 Severity Index Levels in ArchitecturalWork

Table 9. Recapitulation of severity index levels in architectural work

Severity Index Frequency	Severity Index Impact	Risk Level
54.21	71	Medium
58.21	68	Medium
61.15	71	Medium
52.32	70	Medium
51.32	57	Medium
32.58	52	Medium
44.42	50	Medium
43.42	47	Medium
68.05	61	Medium
47.37	48	Medium
16.79	60	Medium
54.26	46	Medium
58.21	51	Medium
47.37	47	Medium
46.37	52	Medium
36.53	47	Medium
43	50	Medium
36.54	60	Medium
36.53	57	Medium
32.58	62	Medium
42.38	51	Medium
23.68	62	Medium
69	56.26	Medium
28.63	64	Medium
40.47	52	Medium
24.68	64	Medium
53.26	71	Medium
58.21	68	Medium
61.16	71	Medium

Severity Index Frequency	Severity Index Impact	Risk Level
52.32	70	Medium
32.58	50	Medium
28.63	48	Medium
32.58	61	Medium
32.58	51	Medium
71	56.21	Medium
65	64	High
57	50.32	Medium
32.58	56	Medium
72	54.26	Medium
50.32	58	Medium
58	50.32	Medium
40.47	49	Medium
28.63	46	Medium
32.58	49	Medium
28.63	51	Medium
53	53	Medium
34.53	66	Medium
31.58	49	Medium
44.42	56	Medium
28.63	59	Medium
60.16	48	Medium
53.26	50	Medium
31.58	49	Medium
36.53	52	Medium
24.68	49	Medium
36.53	46	Medium
51	36.53	Medium
47.32	51	Medium
32.58	51	Medium
51	36.53	Medium

3.2.3 Severity Index Levels in MEP Work

Table 10. Recapitulation of severity index levelsin mep work

Severity Index Frequency	Severity Index Impact	Risk Level
32.58	49	Medium
66.05	49	Medium
52.32	48	Medium
32.58	48	Medium
44.42	53	Medium
51	69	Medium
44.42	60	Medium
40.47	64	Medium
36.53	51	Medium
51	69	Medium
36.53	49	Medium
32.58	48	Medium

Severity Index Frequency	Severity Index Impact	Risk Level
52.32	51	Medium
52.32	49	Medium
40.47	61.05	Medium
48	50	Medium
49	61	Medium
49	65	Medium
45	62	Medium
58	65	Medium
47	70	Medium
48	66	Medium
46	32.58	Medium
48	40.47	Medium
61	47	Medium
50	53	Medium
51	51	Medium
48	50.36	Medium
55	54.36	Medium
53	68	Medium
63	49	Medium
66	58	Medium
62	67	High
32.58	63	Medium
40.47	55	Medium
49	47.37	Medium
63	73.14	High
50	56.26	Medium

3.3 Determining Control

3.3.1. Mobilization Vehicle Slips *Control*

Table 11. Mobilization vehicle slips control

No	Description	Activity
1	Engineering control	Create mobilization routes with adequate project safety signs.
2	Administrative control	Maintain cleanliness of the mobilization route from debris or garbage.
3	Human behavior aspects	Provide supervision and ensure the rider is in good condition

3.3.2 Panel Installation Control

Table 12. Panel installation control

No	Description	Activity
1	Engineering control	Plan execution procedures with hazard identification on each execution item
2	Administrative control	Supervise or control the cleanliness and air pollution of the work area
3	Human behavior aspects	Briefing workers on implementation procedures and giving warnings to focus on work.

3.3.3 Electrical Installation

Table 13. Electrical installation control

No	Description	Activity
1	Engineering control	Use of personal protective equipment
2	Administrative control	Replace of workers have compentence and experience
3	Human behavior aspects	Give strict sanctions to workers if they do not use PPE

4. CONCLUSION

The highest value of severity index frequency and impact is slipping mobilization vehicles as a hazard identification with the risk of accidents, namely vehicles falling on workers, with SI values of frequency and impact of 69% and 71%, respectively. Furthermore, the second severity index value is the installation of formwork panels as a hazard identification with the risk of accidents, namely workers being hit by panels, with SI values of 67% and 70%, respectively. Finally, the third severity index value is electrical installation as hazard identification with the risk of accidents, namely electrocution, with SI values of 63% and 73%, respectively. The total of 49 hazard identification in the project construction work, there are 142 accident risks, with a percentage of 14% of the risks included in the high-level risk criteria, 86% included in the medium-level risk criteria, and there are no risks in the low-level risk criteria. Control is divided into two types, namely control planning and post-accident. Control planning is a preventive activity planned before work is carried out in the hope of reducing or eliminating the risk of accidents from the impact of occupational hazards.

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