Jurnal Teknik Sipil,
Vol. 17, No.1, 2024, Hal 1-12
p-ISSN: 2963-7287 e-ISSN: 2963-6701

JURNAL TEKNIK SIPIL
Universitas 17 Agustus 1945 Semarang
Jurnal Home Page: https://jurnal2.untagsmg.ac.id/index.php/JTS

The Risk Analysis of Work Accidents Using The Bowtie Method in The Ciputra Hospital Construction Project

Risda Yasinta Dewi[1*], I Nyoman Dita Pahang Putra[1]
[1]Departement of Civil Engineering, University of Pembangunan Nasional Veteran Jawa Timur
**Email:* risdayasinta@gmail.com

Diterima Mei 2024; Disetujui Mei 2024; Dipublikasi Juni 2024

Abstract. The condition of work accident risk is a critical factor that needs to be taken seriously. Related to the construction of the Ciputra Hospital Project located on Jl. Made Selatan - Citraland Surabaya, the Ciputra Hospital project is planned to be built on nine floors with a building area of 23,000 m2, which will allow for various occupational accident risks. So, a risk analysis is needed to identify hazards that can occur. In this study, data collection was carried out through interviews and also distribution questionnaires. Questionnaires are used to find probability and severity scales, and questionnaires are distributed to project expert staff. After obtaining the results from the questionnaire, a risk assessment is carried out by finding the probability index and severity index and then determining the category with the risk matrix. After determining the category, the analysis was carried out using the bowtie method. The result of this study is to determine the most dominant risks, namely workers being punctured by sharp equipment when installing formwork, workers falling from a height when installing formwork, and workers being hit by a bar bender machine when forming. After analyzing using the bowtie method, it was found that the causes of the risk of accidents that occurred included workers in a tired condition, lack of concentration, and carelessness, incomplete use of PPE, undisciplined workers at work, no safety at the job site, bad weather, inexperienced workers, poor machine conditions.

Keywords: *work accident risk analysis, risk matrix, bowtie method*

1 Introduction

The amount of development today shows the development of the construction services industry sector. Construction projects are jobs that are very high risk of work accidents. As in Indonesia at this time, the number of work accidents is still high; this is due to the lack of competent labor experts in their fields [1]. According to data from the Ministry of Manpower (Kemenaker), in 2023, there were 347,855 cases of accidents that occurred in construction projects [2]. A work accident is an undesirable incident in the workplace. These accidents can result in injury or death to workers. This, of course, can result in losses for both sufferers or victims and related parties materially.

Workplace accidents can cause serious injuries and even loss of life and harm the company. Accident risk is something that has the potential to occur at any time. So, it is necessary to have proper risk management control to minimize risk. Minimizing risk is expected to contribute significantly to the smooth running of construction projects.

Risk is the effect of uncertainty in an aspect. It refers to an event or occurrence that has several causes. This risk event is usually referred to as an incident or accident. This incident occurs when an aspect such as finance, health, and safety deviates from existing negative or positive expectations (SNI ISO Guide 73: 2016).

The condition of work accident risk is a critical factor that needs to be taken seriously. Related to the construction of the Ciputra Hospital Project located on Jl. Made Selatan - Citraland Surabaya, where this allows the opportunity for various occupational accident risks. Ciputra Hospital Project is planned to be built on nine floors with a building area of 23,000 m2. This project is large enough to have a high risk of work accidents. So, a risk analysis is needed to identify hazards that can occur. Various methods can be used to analyze the factors that cause risk. This research uses the Bowtie Method to analyze the risk of work accidents. The Bowtie method aims to determine the causes of work accidents, what impacts are generated, and how controls can be carried out to minimize the dominant sources of work risk during the construction process of the Ciputra Hospital Project.

Therefore, the purpose of this research is to apply the Bowtie method in the construction of Ciputra Hospital so that it is expected to reduce the impact caused by the risk of accidents that occur.

2 Research Methods

This research is a case study to identify and analyze the risk of work accidents in the Ciputra Hospital construction project. This research focuses on determining the causes, impacts, and controls of the most dominant possibility of work accidents.

Figure 1. Ciputra Hospital Project Site Plan

(*Source: Ciputra Hospital project data*)

Jurnal Teknik Sipil,
Vol. 17, No.1, 2024, Hal 1-12
p-ISSN: 2963-7287 e-ISSN: 2963-6701

Data collection techniques were surveyed using questionnaires. The method used is a descriptive survey to describe a series of events or conditions. Below is a flowchart delineating the research implementation:

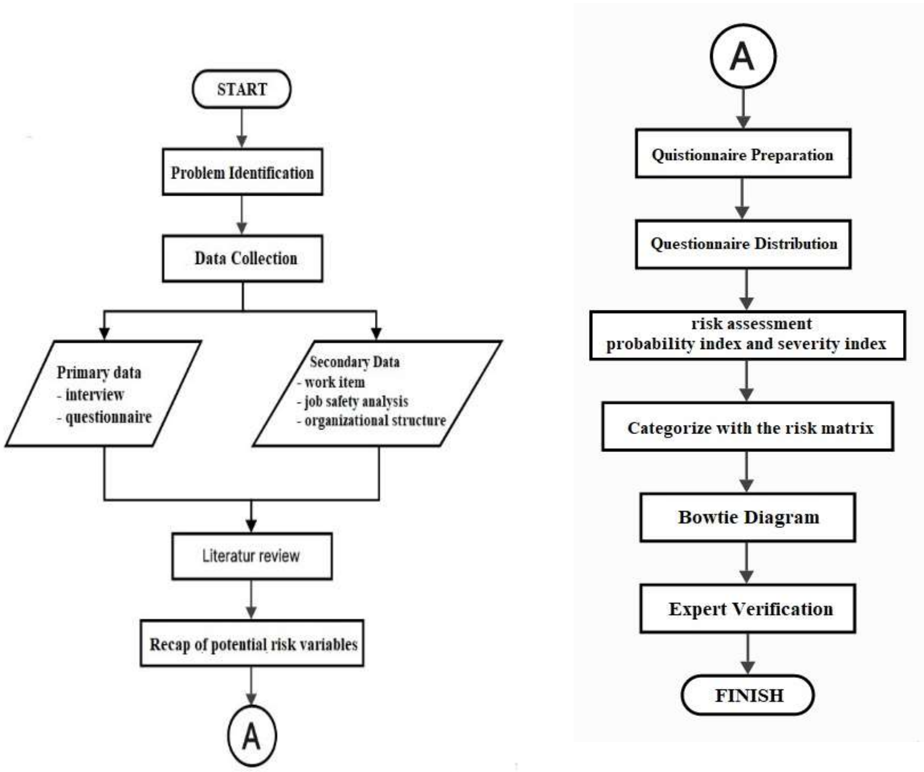

Figure 2. Research Flowchart

3 Results and Discussion

3.1 Risk Identification

Risk identification is an effort made systematically by companies or individuals to find and understand potential risks that may arise during the implementation of activities [3]. The main purpose of risk identification is to recognize possible threats to the company's plans, enabling the company to deal with potential problems more proactively and take appropriate preventive action. According to (Government Regulation No. 60 of 2008), risk identification is defined as a process that includes determining the elements of what, where, when, why, and how an event can occur so that it has a negative impact on achieving objectives. Potential risks can be seen in the following table:

Table 1 Potential Risk Variables

No	Work	Danger	Potential Risks	Source
1	Preparatory Work	Land clearing using excavators	1a. Workers crushed by heavy equipment 1b. Worker hit by heavy equipment	[4]; [5]
		Making site offices and warehouses with not strong materials	1c. Workers crushed by materials	
2	Quarry and Urugan Works	Landslide-prone soil conditions	2a. Workers buried by landslide material 2b. Workers mired 2c. Machine rollovers	[6]; [4]; [5]
		underground electric current	2d. Workers electrocuted	
		Waterlogged excavated pits	2e. Workers affected by dengue disease	
		Unsafe open dug pits	2f. Workers fall	
		use of TC heavy equipment	2g. Sling break up	
3	Formwork work	Installation of formwork using sharp equipment	3a. Punctured Worker 3b. Scratched workers 3c. Workers truncated	[4]; [5]
		High-altitude mounting	3d. Worker falls from a height	
		Installation of non-sturdy formwork	3e. Workers crushed by formwork 3f. Workers pinched formwork 3g. Workers scratched by iron	
4	Bore Pile Foundation Work	Machine drilling of soil	4a. Pinched Workers 4b. Workers Exposed to oil spills	Project JSA Data
		Ironing for the foundation	4c. Workers Pierced by wire 4d. Workers Pinched by iron bending tools	
		Insertion of foundation iron into the pit	4e. Workers crushed by iron	
		pile casting	4e. Workers exposed to concrete liquid	
5	Foundry work	Casting at high altitude	5a. Worker falls from a height 5b. Workers crushed by materials / tools	[6]; [4]; [5]
		Use of concrete pump	5c. Workers sprayed mortar 5d. The machine crashed into surrounding material	
		Use of electrical tools (generators)	5e. Fire due to electrical short circuit 5f. Workers electrocuted	
6	ironing work	Use of Bar Bander Machine	6a. Workers injured by machines	[4]; [5]
		Ironing at high altitude	6b. Workers fall during ironing 6c. Workers crushed by materials	
		irregular storage of iron	6d. Workers pierced by iron 6e. Workers scratched by iron	
7		Ceramic cutting	7a. Exposed to dust exposure	[4]; [6]

	tile installation	Use of burrs	7b. Workers exposed to machines	
			7c. Workers electrocuted	

No	Work	Danger	Potential Risks	Source
8	Beam and Column work	Material Lifting with Tower Crane	8a. Workers crushed by falling materials	[4]; [6]
			8b. Stower crane hit workers	
			8c. Broken jib	
		Dust cleaning using compressor	8d. Workers short of breath exposed to dust	
			8d. Workers' eyes are exposed to dirt and dust	
		Work at height	8e. Workers fall	
		porous formwork	8f. Workers mired	
9	Gypsum ceiling installation	Install wall angle &; angle bracket	9a. Workers electrocuted	Project JSA Data
			9b. Workers exposed to screw reflections	
			9c. Workers fall from a height	
		Gypsum Board Installation	9d. Workers crushed by materials	
			9e. Pinched workers	
			9f. Workers experience eye irritation	
		Compound work & sanding	9g. Workers inhale compound dust	
		Installation of rockwool insulation	9h. Workers experience skin irritation	
			9i. Workers inhale rockwoll dust	
10	Installation of acp for façade	ACP material carried by strong winds	10a. Workers crushed by materials	[4]; [6]
			10b. Damaged material	
		Use of gondolas	10c. Worker falls from a height	

3.2 Risk Assessment

Risk assessment is the process of evaluating risks originating from hazards by considering the effectiveness of any existing controls, as well as making decisions regarding risk acceptance [7].

Risk assessment is carried out with reference to the Australian Standard/New Zealand Standard for Risk management scale (AS/NZS 4360: 2004). In this study, there are 2 parameters used in risk assessment, namely probability and severity.

Table 2 Severity Scale in AS/NZS 4360 Standard

Level	Description	Explanation
1	Insignificant	No injury, little financial loss
2	Minor	Minor injury, little financial loss
3	Moderate	Moderate injury requires medical treatment, major financial loss
4	Major	Serious injury > 1 person, major loss, production disruption
5	Catastrophic	Fatal > 1 person, very large losses and very broad impact, cessation of all activities

Table 3 Probability Scale in AS/NZS 4360 Standard

Level	Description	Explanation
A	Almost Certain	May occur at any time
B	Likely	Occurs frequently
C	Possible	May occur occasionally
D	Unlikely	Rarely occurs
E	Rare	Almost never, very rarely occurs

Probability and severity scale data collected from the questionnaire were analyzed using the Importance Index consisting of Probability Index and Severity Index. [8].

The Probability Index states the frequency of occurrence of risk factors that affect project performance. Here is the formulation:

$$PI = \frac{\sum_{i=0}^{4} ai .xi}{4N} \text{ x } 100\%$$

Severity index expresses the severity of risk factors that affect project performance. The following is the formulation:

$$SI = \frac{\sum_{i=0}^{4} ai .xi}{4N} \text{ x } 100\%$$

Where:

a = Rating Constant (Example for probability, 0 = rare and 4 = almost certain)

n = Respondent Probability

i = 0,1,2,3,4,…….

N = Total Respondents

According to [9], The index of probability and severity can be used to categorize these factors with the following formula:

5. Extremely Effective : 80% < I ≤ 100%
4. Very Effective : 60% < I ≤ 80%
3. Moderately Effective : 40% < I ≤ 60%
2. Ineffective : 20% < I ≤ 40%
1. Extremely Ineffective : 0% < I ≤ 20%

The results of the probability and severity assessment are then entered into the risk matrix table below in order to determine the priority for risk control. The following is a risk matrix table based on AS/NZS 4360:

Table 4 Risk Matrix in AS/NZS 4360 Standard

probability	Severity				
	Insignificant (1)	**Minor (2)**	**Moderate (3)**	**Major (4)**	**Catastrophic (5)**
Almost certain (5)	High	High	Extreme	Extreme	Extreme
Likely (4)	Moderate	High	Extreme	Extreme	Extreme
Possible(3)	Low	Moderate	High	Extreme	Extreme
Unlikely(2)	Low	Low	Moderate	High	Extreme
Rare (1)	Low	Low	Moderate	High	High

The results of all calculations of all variables can be seen in table 4 as follows:

Table 5 Probability Index and Severity Index Recapitulation

No	*probability Index* (PI)	*Rank*	*Severity Index* (SI)	*Rank*	*Risk Matrix*
1a	29%	2	93%	5	E
1b	39%	2	100%	5	E
1c	43%	3	75%	4	E
2a	39%	2	71%	4	H
2b	46%	3	43%	3	H
2c	25%	2	71%	4	H
2d	39%	2	75%	4	H
2e	7%	1	7%	1	L
2f	50%	3	61%	4	E
2g	50%	3	79%	4	E
3a	61%	4	61%	4	E
3b	68%	4	43%	3	E
3c	50%	3	86%	5	E
3d	61%	4	86%	5	E
3e	32%	2	54%	3	M
3f	25%	2	43%	3	M
3g	46%	3	39%	2	M
4a	36%	2	46%	3	M
4b	14%	1	7%	1	L
4c	36%	2	46%	3	M
4d	50%	3	71%	4	E
4e	36%	2	61%	4	H
4f	25%	2	18%	1	L
5a	54%	3	86%	5	E
5b	50%	3	79%	4	E
5c	29%	2	25%	2	L
5d	39%	2	68%	4	H

No	*probability Index* (PI)	*Rank*	*Severity Index* (SI)	*Rank*	*Risk Matrix*
5e	46%	3	64%	4	E
5f	54%	3	86%	5	E
6a	64%	4	75%	4	E
6b	43%	3	71%	4	E
6c	46%	3	71%	4	E
6d	36%	2	54%	3	M
6e	54%	3	46%	3	H
7a	57%	3	25%	2	M
7b	50%	3	75%	4	E
7c	43%	3	64%	4	E
8a	43%	3	89%	5	E
8b	25%	2	89%	5	E
8c	29%	2	86%	5	E
8d	36%	2	11%	1	L
8e	46%	3	7%	1	L
8f	57%	3	86%	5	E
8g	46%	3	50%	3	H
9a	36%	2	64%	4	H
9b	25%	2	32%	2	L
9c	43%	3	71%	4	E
9d	39%	2	61%	4	H
9e	21%	2	25%	2	L
9f	25%	2	7%	1	L
9g	50%	3	21%	2	M
9h	14%	1	4%	1	L
9i	39%	2	14%	1	L
10a	46%	3	64%	4	E
10b	57%	3	43%	3	H
10c	46%	3	96%	5	E

Based on table 4, plotting can be done into a risk matrix by taking a risk scale between 16-25. Then the results obtained are 3A, 3D, 6A. Then it is known that there are 3 variables with an "extreme" risk level, namely in variable 3A (Workers punctured by sharp equipment when installing formwork) with a scale of 16, 3D (workers falling from a height) with a scale of 20, and 6A (workers hit by a bar bender machine when forming) with a scale of 16. Variables with an "extreme" risk level have a considerable influence on the implementation of the project and are considered dominant, so it is appropriate to re-analyze the causes, impacts, and controls of these risk variables using the Bowtie method.

4 Bowtie Method

After classifying the risk matrix, 3 risk variables with extreme levels were obtained and then analyzed using the bowtie method to determine the causes, impacts, and controls of each extreme risk that occurred. [10]. The following is a bowtie diagram of the most dominant occupational accident risks:

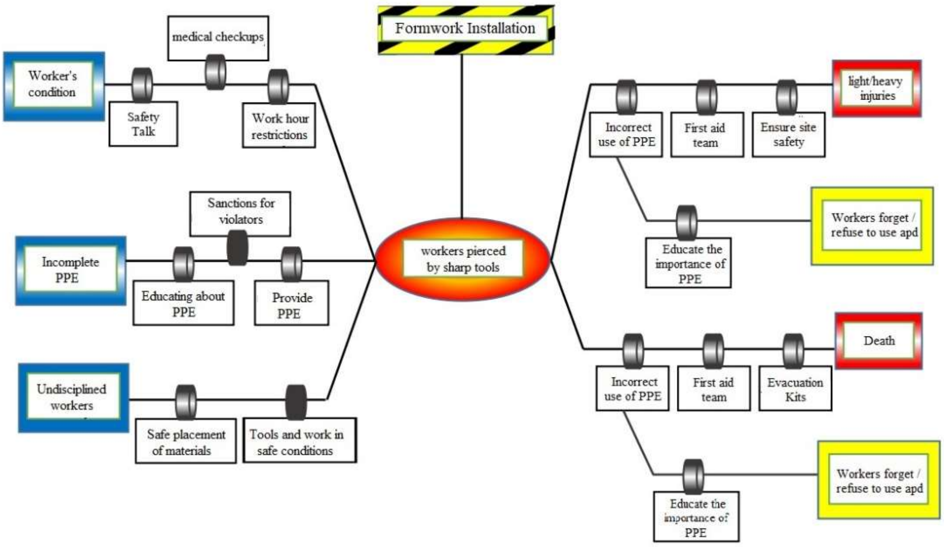

Figure 3 Bowtie Diagram of Worker Pierced by Sharp Equipment

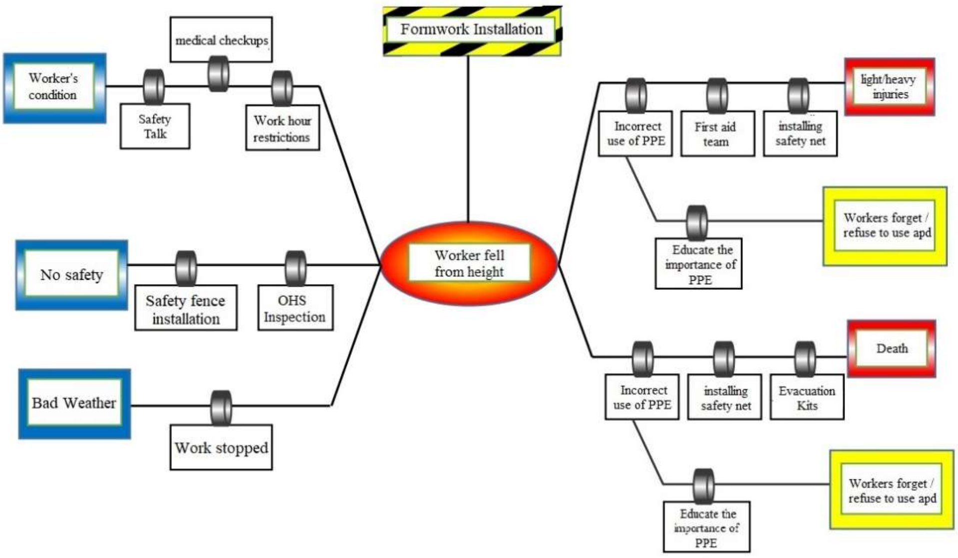

Figure 4 Bowtie Diagram of a Worker Falling from Height

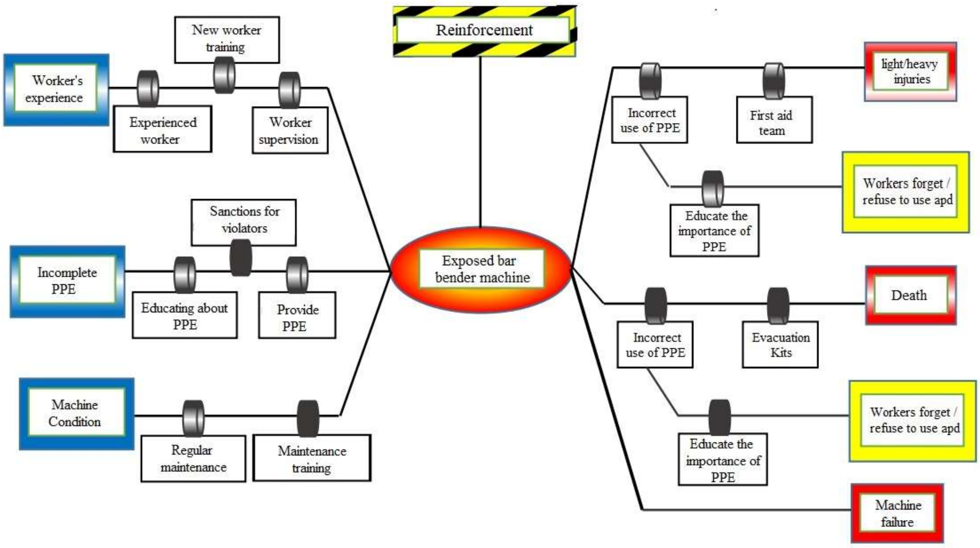

Figure 5 Bowtie diagram of worker exposed to bar bender machine

5 Conclusion

Based on the results of the risk analysis that has been carried out, it can be concluded that:

1. 3 risk variables with extreme levels were obtained, namely, workers being punctured by sharp equipment when installing formwork (3A), workers falling from a height when installing formwork (3D), and workers being hit by a bar bender machine when forming (6A).
2. The causes, impacts, and controls that have been obtained from the bowtie method are as follows:

a. Workers were punctured by sharp tools during formwork installation (3A) due to (a) workers being tired, lacking concentration, and careless: safety talk, routine health checks, and limiting working hours. (b) Incomplete PPE: providing education about PPE, penalizing workers who do not use PPE, and providing PPE according to the number of workers. (c) Workers are not disciplined at work: placing material tools in a safe place, ensuring that work tools and work positions are safe. The impact of this risk is (a) Workers are lightly/heavily injured: use PPE according to company regulations, provide a first aid team or first aid team, and ensure safety at the scene. (b) death: PPE in accordance with company regulations, providing a first aid team or first aid team, and providing evacuation equipment. Escalation factor: workers forget or refuse to use PPE, control: educate workers about the importance of using PPE.

b. Workers fell from a height during formwork installation (3D) due to (a) workers being tired, lacking concentration, and careless: safety talk before starting work, regular health checks for workers, and restrictions on working hours. (b) no safety guards at the work site: installation of safety fences at the edge of the building structure, and conducting safety inspections. (c) bad weather: stop work to avoid work accidents. The impacts of this risk are (a) light/heavy injuries to workers: use PPE according to company regulations, provide a first aid team, and install safety nets. (b) death: use PPE in accordance with company regulations, install safety nets, and provide evacuation equipment. Escalation factors: workers forgetting or refusing to use PPE, control: educating workers about the importance of using PPE.

c. Workers were exposed to the bar bender machine during concreting (6A) due to (a) inexperienced workers: selecting workers with experience, providing training to new workers, and supervising and assisting workers. (b) incomplete use of PPE: providing education and understanding about PPE, sanctioning workers who do not use PPE, and providing PPE according to the number of workers. (c) poor machine condition: routine machine maintenance and conducting machine maintenance training to workers. The impacts of the risks are (a) light/heavy injuries to workers: use of PPE according to company regulations and provide a first aid team. (b) death: use of PPE according to company regulations and provide evacuation equipment. (c) Damage to the bar bender machine can also be an impact of this risk. Escalation factor: workers forget or refuse to use PPE, control: educate workers about the importance of using PPE.

References

[1] R. N. Erlangga, I. Widiasanti, and R. E. Murtinugraha, "Pengaruh Tingkat Kompetensi Ahli Keselamatan Konstruksi terhadap Angka Kecelakaan Kerja di Sektor Konstruksi: Literature Review," vol. 8, no. 1, pp. 5046-5054, 2024.

[2] F. S. Pratiwi. (2024). *Data Jumlah Kasus Kecelakaan Kerja di Indonesia Menurut Provinsi pada 2023*. Available: https://dataindonesia.id/tenaga-kerja/detail/data-jumlah-kasus-kecelakaan-kerja-di-indonesia-menurut-provinsi-pada-2023

[3] J. Apriyan, H. Setiawan, and W. Ervianto, "Analisis risiko kecelakaan kerja pada proyek bangunan gedung dengan metode FMEA," vol. 1, no. 1, pp. 115-123, 2017.

[4] R. N. Gusti and P. A. Wiguna, "Analisis Risiko Kecelakaan Kerja pada Proyek Pembangunan Gedung Kampus II UINSA Surabaya," vol. 10, no. 2, pp. C185-C191, 2021.

[5] B. Bramantio and F. Rachmawati, "Analisis Risiko Kecelakaan Kerja Menggunakan Metode Bowtie pada Proyek The Grandstand Surabaya," vol. 10, no. 2, pp. D170-D175, 2021.

[6] W. B. Veroza and C. B. Nurcahyo, "Analisis Risiko Kecelakaan Kerja Pada Proyek Spazio Tower II Surabaya Mengunakan Metode Bowtie," vol. 6, no. 2, pp. D202-D207, 2017.

[7] A. T. Masjuli, Amri Abdul Kasim *Sistem Manajemen Keselamatan dan kesehatan kerja Berbasis SNI ISO 45001:2018*. 2019.

[8] L. Le-Hoai, Y. D. Lee, and J. Y. Lee, "Delay and cost overruns in Vietnam large construction projects: A comparison with other selected countries," vol. 12, pp. 367-377, 2008.

[9] A. Peruzzi, W. Kriswardhana, and A. Ratnaningsih, "Risk Assessment Kecelakaan Kerja dengan Menggunakan Metode Domino Pada Proyek Apartemen Grand Dharmahusada Lagoon," vol. 6, no. 2, pp. 103-116, 2020.

[10] I. A. Alfarezi, J. W. Soetjipto, and S. Arifin, "Analisis Risiko Keselamatan Dan Kesehatan Kerja (K3) Pada Masa Pandemi Covid-19 Dengan Metode Bowtie Analysis," vol. 10, no. 2, pp. 96-105, 2021.