Journal of Mechanical, Civil and Industrial Engineering
ISSN: 2710-1436
DOI: 10.32996/jmcie
Journal Homepage: www.al-kindipublisher.com/index.php/jmcie

JMCIE
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Occupational Accident Risk Analysis using Failure Mode and Analysis Method: A Case Study of X City Main Market Development Project

Nur Afni Fadila[1] ✉ Achfas Zacoeb[2] and Ming Narto Wijaya[3]
[123]Departement Of Civil Engineering, Brawijaya University, Malang
Corresponding Author: Nur Afni Fadila, **E-mail**: nurafnifadila17@gmail.com

| ABSTRACT
Construction Projects are a work sector that has a high level of work accident risk. This is due to the lack of awareness of the importance of implementing a good Construction Safety Management System (SMKK) following applicable laws and regulations, often the application of the Construction Safety Management System on a project is considered only as a costly expense, not as an investment to prevent work accidents but only is considered to provide a level of loss from the project itself. But, in the construction of the Main Market of City X, there was a work accident; an analysis was carried out using the Failure Mode And analysis method, several works with a high-risk level, namely formwork demolition work, installation work and WF steel assembly work with each value of 48 risk priority numbers with a risk map value of 19, ceiling frame assembly work with a value of 36 risk priority number with a risk map value of 17, Pile head bore work, ceiling material transportation work from storage, test commissioning work with each value of 32 risk priority numbers with a risk map value of 19.

| KEYWORDS

Work Accident, Construction Work Safety Management, FMEA Method

| ARTICLE INFORMATION

ACCEPTED: 17 May 2023 **PUBLISHED:** 19 June 2023 **DOI:** 10.32996/jmcie.2023.4.2.7

1. Introduction

Currently, Indonesia's construction development has made a lot of progress, especially in the development of construction infrastructure. The large number of large projects undertaken requires more manpower, which can contribute greatly to high accident rates. Injuries and deaths due to accidents in the construction industry sector are inherent obstacles because the construction industry sector is more responsible than other industrial sectors (Saeed, 2017).

Construction projects are a work sector that has a high level of accident risk, this is due to the low awareness of the importance of implementing a good Construction Safety Management System (SMKK), and by applicable laws and regulations, often the application of the Construction Safety Management System on a construction project is considered only as a costly expense, not as an investment to prevent work accidents but is considered to provide the level of loss of the construction project itself (Ibrahim, 2020).

Construction Safety Management System is the fulfillment of Security, Safety, Health, and Sustainability Standards as intended by ensuring the safety of construction engineering, construction safety and health, public safety, and environmental safety. (Regulation of the Minister of Public Works and Public Housing Number 10 of 2022 article 2).

The weakness of SMKK in the implementation of construction can cause several problems, including; (1) Project cost overruns, (2) delays in project completion time, (3) physical damage to projects due to vandalism, (4) labor strikes, (5) work accidents and so on. All of them have implications for reduction and can even result in losses (Suparno et al., 2019).

Given the high urgency of work safety in the construction sector in Indonesia, the government has regulated the implementation of the law and the obligations in its implementation in all sectors of the construction industry without exception. This is done to minimize the risk of work accidents so that *zero accidents* can be created (Paramapara, 2018).

The X City Main Market Development Project is one of the Construction Projects that have a high risk and work accidents; based on interviews with Quality Health and Safety Engineering (QHSE) Construction Service Providers and Management, there have been working accidents on pile head boredom work and ironing work. The work accident occurred due to a large number of workers, a lack of understanding of workers on field implementation methods, workers not following Standard Operating Procedures (SOP), and a lack of self-awareness in the use of personal protective equipment (PPE); then further work on accident risk analysis is needed in the X City Main Market Development Project. The benefit of this research is as a reference source for companies to reduce the risk of work accidents.

2. Literature Review

According to the Regulation of the Minister of Public Works and Public Housing Number 10 of 2021 Article 1 Paragraph 1 states that a construction failure is an event due to negligence at the stage of construction work due to non-fulfillment of security, safety, health, and sustainability standards resulting in loss of property, working time, death, permanent disability, and environmental damage.

Based on the Regulation of the Minister of Public Works and Public Housing No. 10 of 2021 concerning Construction Safety Management System Guidelines, it is stated that the Construction Safety Management System is part of the construction work implementation management system to ensure the realization of construction safety. Every service user and service provider in implementing construction must apply the fulfillment of Security, Safety, Health and Sustainability Standards by guaranteeing: (1) construction engineering safety, (2) safety and construction, (3) public safety and (4) environmental safety.

According to the International Labour Organization (ILO), factors that cause work accidents include: (1) organizational planning includes failures in technical planning, rigid inappropriate time limits, assignment of work to inappropriate contractors, (2) implementation of work covering work that has been damaged, materials that are not suitable for use and material damage, (3) management and work methods include inadequate job preparation, inadequate equipment testing, improper instruction procedures, unqualified labor and lack of supervision of inadequate work, (4) job behavior includes lack of responsibility, doing work that is not his authority, bad behavior, such as lack of concentration at work, decreased physical condition, making rules, labor that does not meet the requirements of expertise and Supervision of workers is inadequate.

Australian New Zealand Standard (1999), the objectives of risk management are: (1) to help minimize the spread of unwanted effects occur, (2) to assist in determining the criteria used to make decisions, (3) to maximize the achievement of organizational goals by minimizing losses, (4) implement management programs efficiently to provide profits, not losses, (5) improve decision making at all levels and (6) Develop the right program to minimize losses in the event of failure.

Stamatis (1995), Failure Mode And analysis (FMEA) is an engineering technique used to define and identify the consequences or consequences of potential failures and reduce the chance of accidents. In analyzing the risk of work accidents, three assessments are needed. The three criteria are carried out risk evaluation and analysis (risk assessment) following the table of assessment criteria for Failure Mode And Analysis (FMEA)

Table 1 Criteria assessment of FMEA

Value	Severity	Occurrence rate	Detection Level
1	No effect	Rarely	Almost certainly
2	Low	Low	Keep
3	Keep	Keep	Low
4	Tall	Tall	Very small
5	Very high	Very high	Undetectable

From the results of the analysis of the three FMEA criteria, it is continued with the stage of finding the Risk Priority Number (RPN) value. The RPN value is obtained from the result of multiplication between the ratio of Severity (S), Occurrence (O), and Detection (D). From the results of the three FMEA criteria, multiplication of the *Severity*, *Occurrence,* and *Detection* ratios obtained the value

of the ratio that is likely to occur, which has a level of risks such as low risk, (low risk) *medium* risk, and high risk (critical risk*)* where if the risk exceeds the tolerance limit, the following is needed in figure 1 of the critical matrix diagram
Hasan (2013), statistical data analysis is carried out to prove data or research results about the variables studied, whether they influence the research conducted, and to support the results of research conducted analyzed through the *Statistical Product and Service Solutions* (SPSS) program. Static tests conducted by researchers are test validity and reliability.

Yusuf and Daris (2018), the validity test is an effort to ensure the level of validity in the draft statements and questionnaire questions submitted by researchers to respondents Data validity tests can be done by comparing the value of count with r table if the value of r is calculated > the value of rtable, the instrument is declared valid (with a significant rate of 5% or 0.05) and if the value of r is calculated < the r-value of the table, the instrument is declared invalid (with a significant rate of 5% or 0.05).

Darma (2021), reliability test are carried out to test the level of variable consensus, the resulting data instruments are reliable. Reliability tests are carried out by comparing the value of Cronbach's alpha with the significant level/level used if the value of Cronbach's alpha> a significant level, then the instrument is declared reliable, and if the value of Cronbach's alpha < a significant level, then the instrument is declared unreliable.

Tabel 2 Reliability Levels

Cronbach's Alpha	Reliability Level
0.00 s/d 0.20	Unreliable
0.20 s/d 0.40	Less Reliable
0.40 s/d 0.60	Quite Reliable
0.60 s/d 0.80	Reliable
0.80 s/d 1.00	Highly Reliable

Source : Darma (2021)

3. Research Methods

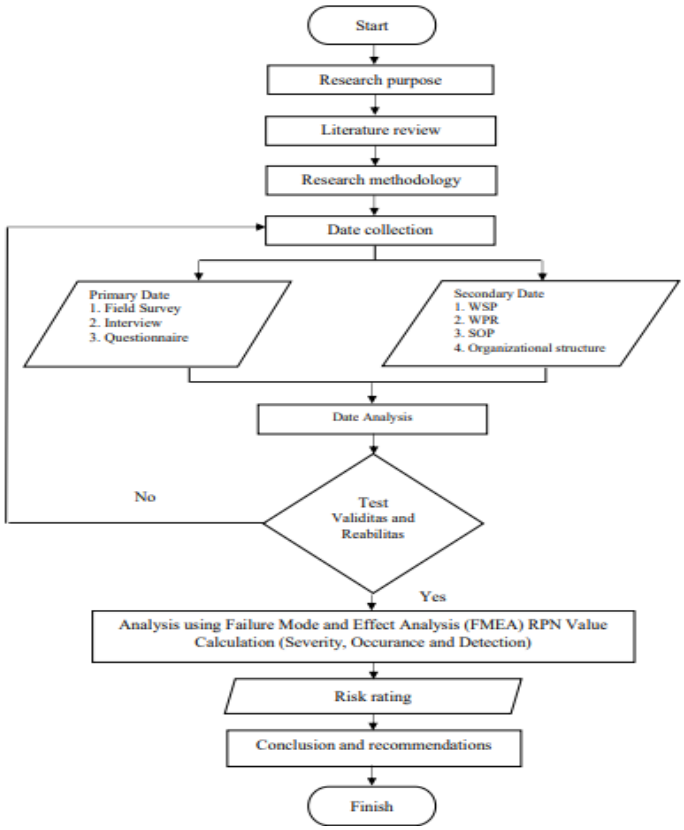

Figure 1. Research Flow Diagram

The data collection method is carried out in the research by collecting data in the form of primary and secondary data. Primary data include direct field observations, interviews, and questionnaires. Secondary data includes work safety plans, work plans and requirements, *Standard Operating Procedures* (SOP), and Organizational Structure.

The research sample of researchers includes individuals from service providers and management with respondent positions consisting of Project Manager of Structure and Architecture, Project Construction Manager and Project Construction Mechanical Electrical Plumbing; Implementation consists of Supervisor, Structural Executor, Architectural Executor, MEP Executor, and Quality Health Safety and Environment). Field Supervisors include Structural Field Supervisors, Architectural Field Supervisors, MEP Field Supervisors, and Field Supervisors at work levels.

Data analysis Before the study, researchers collected literature related to identifying risks that exist in the Construction of the City X Main Market Project. The following are the steps of researchers in conducting research: (1) Identify what risks are likely to occur in work on the City X Main Market Development Project. (2) Making questionnaires based on the results of primary data (direct surveys and interviews) and secondary data to service providers and construction management. (3) distribution of questionnaires. (4) A Validity Test is conducted to determine whether the statement or question from the questionnaire is valid or not. (5) Reliability Test is carried out to determine the level of consistency of what research variables are reliable or not (6) Analysis of data that has been obtained using the Failure Mode and Effect Analysis (FMEA) method to obtain a Risk Priority Number (RPN). (7) Rank the Risk Priority Number (RPN) to determine the greatest possible risk that will occur.

4. Results and Discussions

Based on the results of interviews and field observations, it is found that jobs that have the potential for workplace accidents After filling out the questionnaire, validity, and reliability testing is carried out using Statistical Product and Service Solutions (SPSS). Then it can be continued with the analysis stage of the FMEA method by finding the Risk Priority Number (RPN) value using three assessment indicators, namely Severity Assessment, Occurrence assessment and Detection assessment From the average assessment results, RPN calculation analysis is carried out by multiplying the average of all indicator values can be seen in Table 2.

Table 2. Risk Priority Number Calculation

No	Job Description	Risk Priority Number (RPN)			
		$\bar{x}$ Severity (S)	$\bar{x}$ Occurrence (O)	$\bar{x}$ Detection (D)	S x O x D
A	Light Brick Laying Work				
A1	Fastening with bender wire for light masonry straightness	3	3	2	18
A2	Work in hot weather	3	3	2	18
A3	Light Brick Pieces	2	3	2	12
B	Plastering and Asian Work				
B1	Plastering and slick material removal using the material lift	2	2	2	8
B2	Installation of stucco and slick	3	3	2	18
B3	Working with scaffolding	3	3	2	18
C	Ceramic Couple Work				
C1	Removal of ceramic material using the material lift	2	2	2	8
C2	Ceramic cutting	4	3	2	24
D	Soil Excavation Works				
D1	Digging with excavator	2	2	2	8
D2	Manual soil excavation	3	3	2	18
D3	Work in hot weather	3	3	2	18
E	Piling Head Bobokan Work				
E1	Pile head bore	4	4	2	32
E2	Iron cutting and piling head splicing using a welding blender	3	3	2	18

E3	Removal of pile pieces using an excavator	3	3	2	18
E4	Work in hot weather	3	3	2	18
F	Formwork Work				
F1	Removal of formwork materials from storage	3	3	3	27
F2	Fabrication of polite and hollow iron materials	3	3	2	18
F3	Fabrication using hammers or nails	3	3	2	18
F4	Formwork disassembly	4	4	3	48
G	Ironing Works				
G1	Transportation of materials from the fabrication area	3	3	2	18
G2	Iron cutting in the fabrication area	3	3	2	18
G3	Binding with bender wire	3	2	2	12
G4	Repeat installation	4	4	3	48
H	Foundry Work				
H1	Concrete picking from mixer car	3	3	2	18
H2	Work in hot weather	3	3	2	18
I	Material Lift Installation Work				
I1	Installation of freight elevator interspersal	2	2	2	8
I2	Installation of control panel and drive engine	2	2	2	8
I3	Falls and slips	2	2	2	8
I4	Power installation and testing	2	2	2	8
I5	Operation	2	2	2	8
I6	Maintenance	2	2	2	8
J	ACP Installation Work				
J1	Perakitan ACP (Asembling)	2	2	2	8
J2	Scaffolding Installation	2	2	2	8
J3	Transportation of materials using freight elevators	3	3	2	18
J4	ACP and Silent Installation	3	3	2	18
J5	Finishing	2	2	2	8
K	Ceiling Installation Work				
K1	Manual transport of ceiling material from storage	4	4	2	32
K2	Ceiling frame assembly	4	3	3	36
K3	Ceiling Installation	2	2	2	8
L	Roof Work				
L1	Material transportation using mobile cranes	2	2	2	8
L2	Installation of curtains	2	2	2	8
L3	Stale blended plate mounting	3	3	3	27
L4	Installation of galvalume horizontal gutters	2	2	2	8
L5	Installation of curtain support elbow iron	3	3	3	27
L6	Installation of wind bond iron	2	2	2	8
L7	WF steel mounting	4	4	3	48
L8	Installation of easel poles	3	3	2	18
M	Mechanical, Electrical, and Plumbing Works				
M1	Marking area	3	3	2	18

M2	PVC pipe installation	3	3	2	18
M3	Hydrant pipe installation	3	3	2	18
M4	Conduit pipe installation	3	3	2	18
M6	Tes Commissioning	4	4	2	32

Based on Table 2, the results of the RPN value in each risk assessment indicator are obtained, followed by the stages of sorting the high value of RPN to the lowest value, the order of RPN values can be seen in Table 3

Table 3. FMEA Analysis Results

No	Job Description	RPN Value	Value Risk Map	Level Risk
1	Formwork material disassembly	48	19	*High Risk*
2	Repeat installation	48	19	*High Risk*
3	Installation and assembly of WF steel	48	19	*High Risk*
4	Ceiling frame assembly	36	17	*High Risk*
5	Pile head bore	32	19	*High Risk*
6	Manual transport of ceiling material from storage	32	19	*High Risk*
7	Tes Commissioning	32	19	*High Risk*
8	Removal of formwork materials from storage	27	14	*Medium Risk*
9	Stale lender's plate mounting	27	14	*Medium Risk*
10	Installation of curtain support elbow iron	27	14	*Medium Risk*
11	Ceramic cutting	24	17	*High Risk*
12	Fastening with bender wire for light masonry straightness	18	14	*Medium Risk*
13	Work in hot weather	18	14	*Medium Risk*
14	Installation of stucco and slick	18	14	*Medium Risk*
15	Working with scaffolding	18	14	*Medium Risk*
16	Manual soil excavation	18	14	*Medium Risk*
17	Work in hot weather	18	14	*Medium Risk*
18	Iron cutting and piling head splicing using a welding blender	18	14	*Medium Risk*
19	Removal of pile pieces using an excavator	18	14	*Medium Risk*
20	Work in hot weather	18	14	*Medium Risk*
21	Fabrication of polite and hollow iron materials	18	14	*Medium Risk*
22	Fabrication using hammers or nails	18	14	*Medium Risk*
23	Transportation of materials from the fabrication area	18	14	*Medium Risk*
24	Concrete picking from mixer car	18	14	*Medium Risk*
26	Work in hot weather	18	14	*Medium Risk*
27	Transportation of materials using freight elevators	18	14	*Medium Risk*
28	ACP and Silent Installation	18	14	*Medium Risk*
29	Installation of easel poles	18	14	*Medium Risk*
30	Marking area	18	14	*Medium Risk*
31	Pvc pipe installation	18	14	*Medium Risk*
32	Hydrant pipe installation	18	14	*Medium Risk*
33	Conduit pipe installation	18	14	*Medium Risk*
34	Wiring	18	14	*Medium Risk*
35	Light Brick Pieces	12	8	*Low Risk*
36	Binding with bender wire	12	8	*Low Risk*
37	Plastering and slick material removal using the material lift	8	7	*Low Risk*

38	Removal of ceramic material using a material lift	8	7	*Low Risk*
39	Digging with excavator	8	7	*Low Risk*
40	Installation of freight elevator interspersal	8	7	*Low Risk*
41	Installation of control panel and drive engine	8	7	*Low Risk*
42	Falls and slips	8	7	*Low Risk*
43	Power installation and testing	8	7	*Low Risk*
44	Operation	8	7	*Low Risk*
45	Maintenance	8	7	*Low Risk*
46	Perakitan ACP (Asembling)	8	7	*Low Risk*
47	Scaffolding Installation	8	7	*Low Risk*
48	Finishing	8	7	*Low Risk*
49	Ceiling Installation	8	7	*Low Risk*
50	Transportation of roofing material using mobile cranes	8	7	*Low Risk*
51	Installation of curtains	8	7	*Low Risk*
52	Installation of galvalume horizontal gutters	8	7	*Low Risk*
53	Installation of wind bond iron	8	7	*Low Risk*

Based on Table 3, it can be known the risk of work accidents that occur in the X City Main Market Development Project using the FMEA method analysis, namely the highest risk, namely demolition work, Formwork material, reinforcement installation work, roof WF steel installation, and kit work, ceiling frame assembly work, pile head bore work, transportation work manual of ceiling material from storage, and test commissioning work.

5. Conclusion

Based on the results of observations and direct interviews with Service Providers and Construction Management in the X City Main Market Development Project, a work accident risk analysis was carried out using the Failure Mode and Failure methods. Analysis (FMEA) then carried out a risk level analysis using the risk matrix of the Department of Public Works and Spatial Planning Circular Number. 04/SE/M/2021 concerning the Implementation of Risk Management Guidelines for the Implementation of Ministry Risk Management Public Works and Public Housing obtained several jobs that have high risk, namely work, demolition work, formwork, repetition installation work, WF steel roof installation and assembly work with a value of 48 RPN, ceiling frame assembly work with a value of 36 RPN, pile head bore work, manual work of ceiling material from storage and test commissioning with a value of 32 RPN.

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