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Analyze of Occupational Health and Safety Risk Factors and Human Resource Quality on the Implementation of Building Construction using Fault Tree Analysis

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ABSTRACT

The Root Causes of Workplace Accidents on Building Projects Using FTA (Fault Tree Analysis) Method. FTA (Fault Tree Analysis) is a technique that can link several event sequences that result in other events. The objectives of this research are: to identify OHS risk factors and the quality of human resources in the construction of high-rise buildings in the Integrated Sports Psychology Building Project at the State University of Surabaya, to evaluate the dominant OHS risk factors and human resources in the construction of the Integrated Sports Psychology Building Project at the State University of Surabaya using the Fault Tree Analysis Method, and to determine appropriate mitigation actions to address OHS risk factors and the quality of human resources in the construction of the Integrated Sports Psychology Building Project at the State University of Surabaya using the Fault Tree Analysis Method. This study focuses on identifying the risk factors for the quality of human resources as construction workers in building construction projects using the Fault Tree Analysis method. This research is descriptive and analytical. The implementation of the Smart Automation Workshop building project at the State Polytechnic of Electronics in Surabaya involves several health and safety-related risk factors. The results of the study show that these risk factors are divided into four categories: Very Small, Small, Moderate, and Large, as well as one special category: Very Large. The identified risks include non-compliance with safety procedures, lack of OHS training or certification for workers, unsafe working conditions, use of unsafe equipment, worker negligence, and inadequate personal protection or safety equipment. To reduce these risks, strict OHS standards and regulatory compliance are needed, as well as the use of safe equipment and technology. In addition, careful worker selection and training, routine inspection and evaluation, appropriate job placement, and competency development are also recommended. Regular maintenance and inspection of concrete molds, compliance with construction regulations, and training on new technology are also needed to ensure project safety and success.

Keywords:

Workplace Accidents, Building Projects, FTA, OHS, Quality of Human Resources.

1. Introduction

Occupational Health and Safety (OHS) is an effort to create safety and protection from various risks of accidents and hazards, both physical, mental, and emotional, for workers, companies, society, and the environment. Based on Indonesian Law Number 1 of 1970 concerning occupational safety and health, every worker has the right to protection for their safety while working, improving their welfare, and increasing national production and productivity [1]. According to data from the Indonesian Social Security Administration (BPJS) Employment, 2017 was recorded as the year with the highest number of work accidents in the construction sector due to the massive development projects. There were around 1,877 work accidents in the construction sector throughout 2017 [2]. Until now, the overall number of work accidents in Indonesia is still relatively high. Data from BPJS Employment recorded 114,235 cases of work accidents in 2019 [3]. Meanwhile, from January-October 2020, this number increased to 177,161 cases of work accidents [4]. Surabaya, as the second-largest city in Indonesia, is increasingly becoming more significant. This capital of East Java has transformed significantly, making it a target for national and multinational companies to realize their business expansion. Infrastructure development in Surabaya is also quite rapid. In 2014, the cumulative number of office buildings was 291,262 square meters, which will increase to 800,000 square meters in the next three years, namely 2015-2018. This number comes from 19 buildings, and the apartment market in Surabaya is only 12% of the number of apartment units in Jakarta, but its growth is so high, namely 142%. The supply from 2015 to 2018 is 25,844 units from 27 projects. The Integrated Building Development Project of Psychology and Sports at Surabaya State University is a project carried out by PT. Nindya Karya. This project is a 7-story building project located on the UNESA Lidah Wetan Surabaya Campus. The construction project has a long working time of 400 days, making it prone to risks that can hinder project activities. In this case, an important aspect to consider is Occupational Health and Safety (OHS) and the quality of human resources as the construction project stakeholders. Based on this statement, risk management is needed to prevent unwanted risks [5] [6]. This prevention can be done by analyzing and identifying risks and responding to risks that have and will occur [7] [8]. Many other methods can be used to identify, measure, and evaluate risks in construction projects [9]. These methods include HAZARD, FMEA (Failure Mode Effect Analysis), CIA (Confidentiality, Integrity, and Availability), FTA (fault tree analysis), audits, and ETA (Event Tree Analysis) [10]. The root cause of work accidents in building projects is analyzed using the FTA (Fault Tree Analysis) method [11]. FTA is a technique that can connect several event sequences that produce several other events [12]. The results of the research using the FTA method obtained agreement on the potential causes of accidents that occurred during the transportation of iron to the field, which were then arranged using the FTA method, resulting in 19 combinations of accident causes. Additionally, this method can also analyze risks more detailedly based on the evaluation results. From the previous research results, this research can be conducted using the FTA method to determine the risk factors of OHS and the quality of human resources in the implementation.

2. Methods

2.1. Research concept

The research in this case study is focused on identifying the risk factors of human resource quality as construction actors in the building development project using the Fault Tree Analysis (FTA) method. This research is descriptive analytical in nature. Descriptive analytical research aims to describe and interpret something, such as existing conditions or relationships, prevailing opinions.

The research was conducted at the UNESA Sports Psychology Integrated Building Development Project.

2.2. Research stages

1. Risk Identification

The risk identification stage involves observation, literature study, interviews, and questionnaire distribution to obtain variables of human resource quality risk factors. The questionnaire is distributed to selected respondents in the population to choose "yes" or "no" answers. If the respondent answers "yes," they will be included in the main questionnaire form. Analysis is carried out through:

a. Main questionnaire distribution using valid variables.
b. Interviews to facilitate respondents in answering.
c. Risk assessment based on the probability and impact of the risk.
d. The assessment results are depicted in matrix diagrams based on frequency and impact.
e. Risk assessment with validity and reliability testing.

2. Validity and Reliability

Testing The next step is to conduct validity and reliability analysis, which aims to obtain validation results from the questionnaire. The equation used for validity testing is the Pearson equation, which measures the linear relationship between two variables and determines the correlation coefficient value. For reliability testing, the Cronbach's Alpha method is used with the help of SPSS software. A high-risk measurement scale is used for risk probability/frequency and impact measurement, which is the Likert scale with a range of numbers from 1 to 5, as follows: Probability level measurement of risk 1 = very rare 2 = rare, 3 = possible, 4 = frequent, 5 = very frequent.
Impact level measurement of risk (I) , 1 = very small , 2 = small , 3 = moderate , 4 = large , 5 = very large For risk level measurement.
A high-risk measurement scale is used for risk probability/frequency and impact measurement, which is the Likert scale with a range of numbers from 1 to 5, as follows: (a) Probability level measurement of risk: 1 = very rare, 2 = rare, 3 = possible, 4 = frequent, 5 = very frequent. (b) Impact level measurement of risk (I): 1 = very small, 2 = small, 3 = moderate, 4 = large, 5 = very large for risk level measurement.
Then, an analysis is conducted using the Severity Index (SI) method. The purpose of this method is to obtain a combination of risk frequency and impact assessments on implementation. After obtaining the level of risk probability and impact category values, the next step is to plot these values on the frequency and impact matrix. Then, to determine the risk rank, it can be plotted on the risk rank matrix. The next analysis is to use the Fault Tree Analysis (FTA) method. The steps in working with the FTA method are as follows: Choosing the problem to be analyzed (problem definition). Drawing a graphical model of the FTA method by finding the top event, then drawing the next events until the root of the problem or basic event. Providing a response or answer from the FTA fault method (FTA solution), which is various possibilities of risk occurrence. If the risk occurs together, it can cause the top event. After that, the combination of events must be determined (minimum cut set ranking).
The steps in determining the combination of events (minimum cut set) are as follows: Modifying the FTA logic gate to be OR and AND gates only. Naming each event. Converting the fault tree into a Boolean algebra equation. Determining the combination of events or the minimum cut set by simplifying the Boolean algebra equation to a simpler equation using Boolean algebra rules.
To facilitate the research, a flowchart of the research and an FTA method flowchart are prepared.

The research flowchart using Fault Tree Analysis method can be seen in Figure 1.

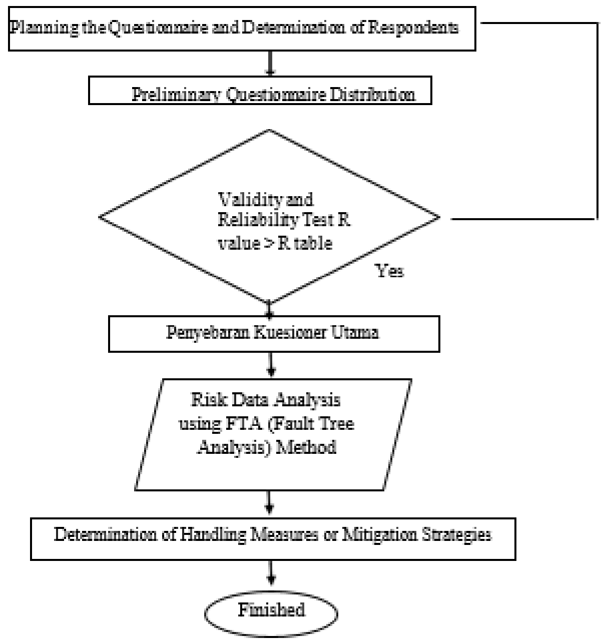

Figure 1. Framework of Research

3. Results and discussions

In analyzing the identification of occupational health and safety (OHS) risk factors and human resource quality in building construction using the Fault Tree Analysis (FTA) method, the identification of risks and analysis of risk causes were conducted on OHS factors and human resource quality. To conduct risk analysis with the FTA method, a fault tree diagram was created. In the fault tree diagram, risks were identified as unwanted events consisting of several risk factors or sub-factors. The research data was obtained through the distribution of questionnaires and interviews with respondents, namely the staff of the Smart Automation Workshop Building Project at the State Electronics Polytechnic of Surabaya, who were equivalent to construction implementers and understood the risks that occurred in project implementation caused by human resource quality factors as construction actors. The data obtained consisted of respondent profiles, project profiles, occurred risks, frequency of risks, risk impact, risk causes, and risk handling in the form of risk response. Before the main questionnaire distribution, a questionnaire was distributed to 2 comparison projects aimed at finding significant research variables for validity testing. The two comparison projects were the Smart Automation Workshop Building Project at the State Electronics Polytechnic of Surabaya and the Integrated Industrial Psychology Construction Development Project.

3.1. Validity test

To test the validity of an instrument using SPSS on a sample, a validity test can be conducted by analyzing the correlation between each item in the instrument with the total score of the instrument. The validity test is conducted to determine whether a questionnaire is valid for each variable. The validity test conducted in this study is presented below:

Table 1. Validity Test on Probability Variables.

Indicator	T value	T table	Description
A1	0,457	0,3687	Valid
A2	0,387	0,3687	Valid
A3	0,784	0,3687	Valid
A4	0,412	0,3687	Valid
B1	0,508	0,3687	Valid
B2	0,433	0,3687	Valid
B3	0,413	0,3687	Valid
B4	0,387	0,3687	Valid
B5	0,752	0,3687	Valid
C1	0,445	0,3687	Valid
C2	0,680	0,3687	Valid
C3	0,381	0,3687	Valid
C4	0,490	0,3687	Valid
C5	0,907	0,3687	Valid
D1	0,420	0,3687	Valid
D2	0,427	0,3687	Valid
D3	0,392	0,3687	Valid
D4	0,804	0,3687	Valid
D5	0,458	0,3687	Valid
E1	0,808	0,3687	Valid
E2	0,701	0,3687	Valid
E3	0,369	0,3687	Valid
E4	0,424	0,3687	Valid
E5	0,387	0,3687	Valid

Based on the above output, it can be seen that the value of the Pearson correlation coefficient (r) for all questionnaire items is greater than the r table value, indicating that all questionnaire items are valid. From the validity testing results in the table above, there were 24 questionnaires that were filled out by 20 respondents in this study. One way to determine which questionnaires are valid and which are not is to find out the r table value first. The formula for r table is df = N-2, so 20-2 = 18, and the r table value is 0.3687. From the validity calculation results in the table above, it can be seen that for all 20 questionnaires, r hitung > r tabel, indicating that all questionnaires are valid because the r hitung value is greater than the r tabel value, which is 0.387

Table 2. Validity Test on Risk Variables.

Indicator	T value	T tabel	Description
A1	0,404	0,3687	Valid
A2	0,561	0,3687	Valid
A3	0,478	0,3687	Valid
A4	0,448	0,3687	Valid
B1	0,775	0,3687	Valid
B2	0,373	0,3687	Valid
B3	0,381	0,3687	Valid
B4	0,407	0,3687	Valid
B5	0,731	0,3687	Valid
C1	0,424	0,3687	Valid
C2	0,381	0,3687	Valid
C3	0,427	0,3687	Valid
C4	0,511	0,3687	Valid
C5	0,730	0,3687	Valid
D1	0,418	0,3687	Valid
D2	0,394	0,3687	Valid
D3	0,460	0,3687	Valid
D4	0,607	0,3687	Valid
D5	0,781	0,3687	Valid
E1	0,422	0,3687	Valid
E2	0,443	0,3687	Valid
E3	0,427	0,3687	Valid
E4	0,583	0,3687	Valid
E5	0,387	0,3687	Valid

3.2. Reliability test

In this study, a reliability test must be conducted to measure the consistency of the questionnaire used to measure the influence of variables. Before conducting the reliability test, a decision-making basis must be established, which is an alpha value of 0.60. A variable is considered reliable if its value is greater than >0.70. If it is smaller, the variable being studied cannot be considered reliable. Based on the output table above, there are N of items indicating the number of questions, which is 24 questions with 2 variables, with a Cronbach's alpha value of 0.942. Based on the decision-making basis above, the questionnaire items are reliable because the Cronbach's alpha value is >0.70.

Table 3. Reliability Test.

Reliability Statistics	
Cronbach's Alpha	**N of Items**
0,912	2

3.3. Calculation of Probability and Impact Values Using the Severity Index Method

The main questionnaire on frequency risk calculation and risk impact calculation used the Likert scale method to measure the probability or frequency of risk variables occurring in high-rise building projects, as well as the resulting impact. The Likert scale used to measure probability or frequency is as follows: 1= very rarely occurs, 2= rarely occurs, 3= may occur, 4= frequently occurs, 5= very frequently occurs. After distributing the main questionnaire and obtaining the probability and impact values of risk variables in the Smart Automation Workshop Building Project - Surabaya State Electronics Polytechnic, an analysis of the results was conducted using the Severity Index (SI) method, which aims to obtain a combination of risk probability and impact assessments on the implementation of the project. The following is an example of calculating the results of the main questionnaire using the Severity Index (SI) method for the variable "Labor Risk": out of 20 respondents, 3 respondents stated that the frequency is very rare, 6 respondents stated that the frequency is rare, and 7 respondents stated that the frequency is possible to occur.

SI3x1+6*2+0*3+7*4+(5*0)17*5 (1)
SI=53,75%

The SI value of 53.75% was obtained for the variable "Labor Risk". Next, the SI value will be converted to the assessment scale according to table 4

Table 4. Variables with High Occurrence Frequency and High Values in Risk Project of Smart Automation Workshop Building - State Polytechnic of Electronic Engineering Surabaya.

NO	RISK TYPES	VALUE SI (100%)	CATEGORY
A2	Shortage of Workers in the Field	56,25	CS
A4	Lack of coordination/communication among workers or between workers and supervisors	60	H
B4	Lack of training from management to workers about occupational safety	40	R
B5	Lack of guidance before carrying out work about occupational safety	54,25	CS
C3	Collapse of concrete molds	71,58	H
D4	Field execution not in accordance with planning	75,00	H
D5	Implementation schedule not in accordance with planning	67,50	H
E1	Educational level has no effect on the quality of human resources as construction workers	65,00	H
E2	Job history has no effect on the quality of human resources as construction workers	66,25	H
E3	Length of work period has no effect on the quality of human resources as construction workers	60,00	H

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3.4. Dominant Risk Factors in OHS Using FTA Method (Fault Tree Analysis)

The FTA (*Fault Tree Analysis*) method is a risk analysis method used to identify the factors that cause an event or damage. FTA is used to create a risk causation tree model consisting of basic events and causal factors. In this case, FTA is used to identify the OHS factors and the quality of human resources that can affect the profitability of the implementation of the Smart Automation Workshop Building Project - State Polytechnic of Electronic Engineering Surabaya.

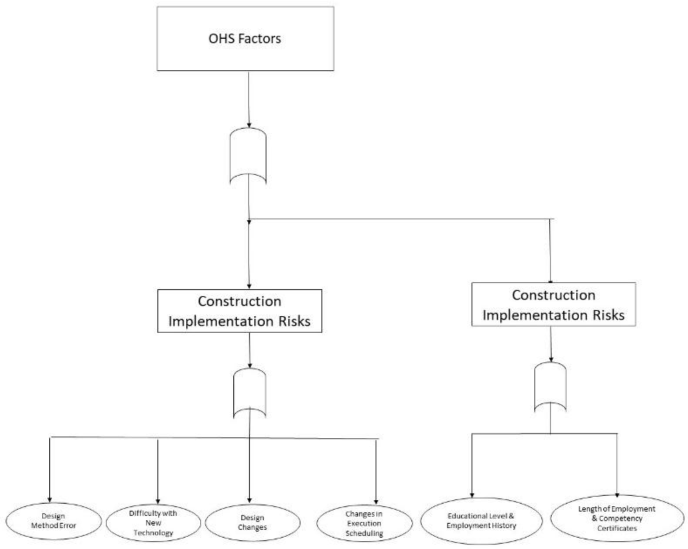

Figure 2. FTA Analysis with Human Resource Quality Risk Factors.

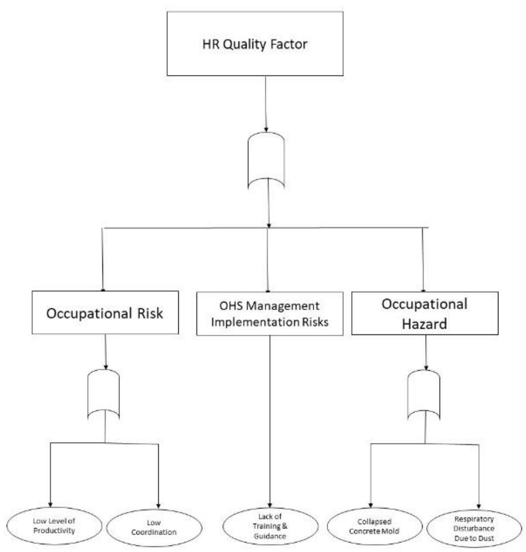

Figure 3. FTA Analysis with Occupational Health and Safety (OHS) Risk Factors.

Based on the second figure, there are five OHS risk factors and five human resource quality risk factors identified. Each risk factor is given a risk description, probability, and FTA risk. Probability refers to the likelihood of the risk occurring in a specific factor, while FTA risk indicates the contribution of the risk factor to the overall risk.

OHS risk factors

A. Labor risk

- A1. Low productivity level of workers: this risk factor has a probability of 2.8 and an FTA risk of 7.28. This means that low productivity level of workers contributes significantly to the overall risk.
- A2. Shortage of workers in the field: this risk factor has a probability of 2.15 and an FTA risk of 5.375. This means that the shortage of workers in the field contributes significantly to the overall risk.
- A3. Low quality of work in the field: this risk factor has a probability of 2.65 and an FTA risk of 7.155. This means that the low quality of work in the field contributes significantly to the overall risk.
- A4. Low coordination/communication among workers as well as workers with their superiors: this risk factor has a probability of 2.35 and an FTA risk of 5.405. This means that low coordination/communication among workers as well as workers with their superiors contributes significantly to the overall risk.

B. Implementation of OHS Management Risk

- B1. Low health and safety at work (OHS) on the project site due to safety regulations that are not implemented in the field: this risk factor has a probability of 2.55 and an FTA risk of 7.14. This means that the low health and safety at work (OHS) on the project site due to safety regulations that are not implemented in the field contributes significantly to the overall risk.
- B2. Not using Personal Protective Equipment (helmets, goggles, masks, ear protection, body harnesses, gloves, safety shoes) Risk B2 on OHS and human resource quality factors is "Not using Personal Protective Equipment (helmets, goggles, masks, ear protection, body harnesses, gloves, safety shoes)".
- To perform risk identification using the FTA method, the steps that can be taken include:
- Determine the causal factor of the risk. The causal factor in risk B2 is worker non-compliance with using personal protective equipment.
- Identify trigger factors that can cause the risk to occur. Triggers in risk B2 include lack of socialization about the importance of using personal protective equipment, lack of supervision and enforcement of rules regarding the use of personal protective equipment, and inadequate availability of personal protective equipment.
- Determine the possible impacts if the risk occurs. Possible impacts on risk B2 include injuries to the head, eyes, face, ears, hands, and feet from sharp, heavy, or thrown objects during the construction process.
- Identify preventive measures that can be taken to prevent the risk from occurring. Preventive measures for risk B2 include increasing socialization about the importance of using personal protective equipment, improving supervision and enforcement of rules regarding the use of personal protective equipment, providing adequate personal protective equipment, and conducting training for the correct use of personal protective equipment.
- Identify mitigation measures that can be taken if the risk has already occurred. Mitigation measures for risk

B2 include providing first aid to injured victims, temporarily stopping the construction process to ensure worker safety, and conducting a reassessment.

3.5. Risk mitigation actions

Risk management using the Risk Reduction Fault Tree Analysis (FTA) method can be implemented, as shown in the table below:

Table 5. Dominant Mitigation Strategies

No.	Risk	Impact	Mitigation
1	Low productivity level of workers	Decrease in project progress and increase in project cost	Selecting quality and experienced workforce. Increasing motivation of workers through incentives and rewards.
2	Low quality of work on site	Potential for defects or damage to buildings	Selecting quality and experienced workforce. Providing adequate training and supervision.
3	Occupational Health and Safety (OHS) Management Risk	Potential for workplace accidents or injuries to workers	Implementing strict HSE standards and complying with regulations. Conducting routine inspections and evaluations to ensure compliance.
4	Low health and safety standards on project sites due to non-compliance with safety regulations on site	Potential for workplace accidents or injuries to workers	Conducting training and socialization related to occupational safety. Ensuring the suitability of personal protective equipment (PPE) and its application in the field.
5	Work that poses a risk of occupational accidents	Potential for workplace accidents or injuries to workers	Implementing strict HSE standards and complying with regulations. Using safe equipment and technology that meets standards.
6	Collapse of concrete molds	Potential for project delays and cost increases	Conducting periodic maintenance and inspections on concrete molds. Using quality and durable concrete molds.
7	Construction Implementation Risk	Potential for environmental changes and legal issues related to construction	Implementing appropriate development regulations and avoiding construction that could potentially damage the environment. Ensuring the completeness and compliance of permits and documents with regulations.

8	Difficulties in using new technology (equipment and methods) in construction and production processes on the project	Construction and production processes hindered, project costs increased, project schedule delayed	Conducting training and introduction to new technology for all workers involved in the project. Involving technology experts in the development and use of new technology. Conducting thorough testing of new technology before it is used in the field. Conducting periodic evaluations of the use of new technology and making improvements if necessary.
10	Design changes	Changes in design can affect project schedule and quality	Efficient and effective design change management. Evaluating the impact of design changes on project schedules and quality. Strong collaboration between project management and design team.
11	Competency Skill Risk	Lack of competence and skills of workers can affect the quality of work	Careful recruitment and selection process. Training and development of workers' skills. Clear task distribution and responsibilities. Routine monitoring and evaluation of workers' performance.
12	Improper job placement	Decreased productivity and work quality, fatigue, workplace accidents	Placing workers in jobs that match their skills and qualifications. Providing training and competency development for workers who need it to perform their assigned tasks well. Ensuring clear and open communication between management and workers regarding job placement. Conducting periodic evaluations and supervision to ensure appropriate and effective job placement.

4. Conclusion

The study conducted a risk assessment of the Smart Automation Workshop Building Project - Surabaya State Polytechnic and identified several occupational safety and health (OSH) risk factors. The risk factors were classified into five categories, including Very Small, Small, Medium, Large, and Very Large. The identified OSH risk factors included non-compliance with safety procedures, lack of training or certification for workers, unsafe working conditions, use of unsafe equipment or machinery, worker carelessness or negligence, and inadequate personal protection or safety equipment. In addition, low coordination/communication among workers and between workers and their superiors, collapse of concrete molds, implementation not in accordance with the plan, and implementation schedule not in accordance with the plan were also identified. The study also used Fault Tree Analysis (FTA) to identify the causes of risks to human resource quality, such as low quality of work on site, risk of OSH management implementation, and inappropriate job placement. To mitigate these risks, the study recommends implementing strict OSH standards that comply with existing regulations, selecting qualified and experienced workers, providing adequate training and supervision, conducting routine inspections and evaluations to ensure compliance, and appropriate job placement based on each worker's skills and qualifications. Furthermore, the study suggests regular maintenance and inspection of concrete molds, application of appropriate construction regulations, and training and introduction to new technology.

5. References

1-Alloysius Vendhi Prasmoro, Murwan Widyantoro, W., 2021, **Analisis Penerapan Program Keselamatan Kerja Pada Lantai Produksi Dengan Metode FAULT TREE ANALYSIS (Fta) Di Analysis of Application Occupational Safety Program on the Production Floor With FAULT TREE ANALYSIS (Fta) Method**, At Pt . Xyz, 21, 2, 75–82.

2- Asmawati, A. L., Juniani, A. I., and Dhani, R, 2017, **Pemilihan Rekomendasi Menggunakan Bca**, 2581, 699–704.

3-Bastuti, S., 2020, **Analisis Risiko Kecelakaan Kerja Dengan Metode Failure Mode and Effect Analysis (Fmea) Dan FAULT TREE ANALYSIS (Fta) Untuk Menurunkan Tingkat Risiko Kecelakaan Kerja (Pt. Berkah Mirza Insani)**, Teknologi : Jurnal Ilmiah Dan Teknologi, 2, 1, 48. https://doi.org/10.32493/teknologi.v2i1.3909

4-Darmawan, D., Puspita, A. D., and Santosa, G., 2022, **Analisis Keselamatan Dan Kesehatan Kerja Dengan Pendekatan Hazard Identification Risk Assessment and FAULT TREE ANALYSIS Pada PT. WGI**, Journal of Industrial and Systems Optimization, 5, 1, 10–17.

5-Ginting, N. S. br, and Kristiana, R., 2020, **Analisis Efektivitas Pengendalian Risiko Kecelakaan Kerja Pada Pekerja Proyek Konstruksi Menggunakan Metode Fine dan FAULT TREE ANALYSIS**, Teknik, 41, 2, 192–200. https://doi.org/10.14710/teknik.v39i3.20265 Ilmiah, J., & Pendidikan, W. (2022). 3 1,2,3. 8(July), 365–378.

6-Kementerian Pekerjaan Umum RI., 2014, **Peraturan Menteri Pekerjaan Umum Nomor 05/PRT/M/2014 Tentang Pedoman Sistem Manajemen Keselamatan Dan Kesehatan Kerja (SMOHS) Konstruksi Bidang Pekerjaan Umum**, Peraturan Menteri Pekerjaan Umum, 41.

7-Lutolf, H., 1977, **Turnover of piecegoods in fibre production**.

8-Maddeppungeng, A., Mina, E., and Dewi, I. P., 2017, **Pengembangan dan Uji Model Sumber Daya Proyek Kontruksi Terhadap OHS (Kesehatan dan Keselamatan Kerja) dan Kinerja Perusahaan (Studi Kasus : Proyek Pembangunan Kontruksi Offshore Provinsi Banten)**, Jurnal Fondasi, 6, 2, https://doi.org/10.36055/jft.v6i2.2475

9-Mariawati, A. S., Umyati, A., and Andiyani, F., 2017, **Analisis penerapan keselamatan kerja menggunakan metode Hazard Identification Risk Assessment (HIRA) dengan pendekatan Fault Tree Anlysis (FTA)**, Industri Servicess, 3c, 1, 293–300. https://jurnal.untirta.ac.id/index.php/jiss/article/view/2108

10 -Nisa, T. F. A., Suyono, H., & Sukmawati, S., 2019, **Identifikasi Risiko Faktor Kualitas Sumber Daya Manusia Menggunakan FAULT TREE ANALYSIS Method Pada Pelaksanaan Pembangunan Bangunan Tinggi**, Journal Rekayasa Sipil Dan Lingkungan, 37–47.

11-Nur, M., and Ariwibowo, O., 2007, **Sipp. Hawley's Condensed Chemical Dictionary**, 4, 1, 55–63. https://doi.org/10.1002/9780470114735.hawley14577

12-Nuriawati, L. and Ismara, K. I., 2018, **Evaluasi Penerapan Keselamatan Dan Kesehatan Kerja (OHS) Berdasarkan FTA , FMEA Dan PHA Di Jurusan TITPL SMK Negeri 1 Magelang**. 8, 6, 490–501. http://journal.student.uny.ac.id/ojs/index.php/mekatronika/article/viewFile/13596/pdf

13- Pasaribu, H. P., Setiawan, H., Ervianto, W. I., Magister, M., Sipil, T., Atma, U., Yogyakarta, J., Magister, D., Sipil, T., Atma, U., and Yogyakarta, J., 2017, **Metode Failure Mode and Effect Analysis (Fmea) Dan FAULT TREE ANALYSIS (Fta) Untuk Mengidentifikasi Potensi Dan Penyebab**, Manajemen Teknik.