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Occupational Accident Risk Analysis in the Production Process of Barokah Furniture Industry Pasuruan Using FMEA (Failure Mode and Effect Analysis) and FTA (Fault Tree Analysis) Methods

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Abstract

This study aims to analyze occupational accident risks in the production process at Barokah Furniture Pasuruan using the Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) methods. The furniture industry involves various potential hazards in its production process, such as the use of cutting tools, dust exposure, and high-risk manual work techniques, necessitating a systematic evaluation to minimize workplace accidents. The FMEA method is used to identify and prioritize risks based on the Risk Priority Number (RPN), calculated from a combination of severity, occurrence, and detection. The analysis results identified 20 failure modes, with the three primary risks having the highest RPN: cuts from saw blades (RPN=250), respiratory issues due to excessive dust (RPN=196), and hand injuries from the use of manual planers and machine knives (RPN=180). Furthermore, a Fault Tree Analysis (FTA) was conducted to map the root causes of each priority failure mode. Based on the analysis, it was found that the main causes of workplace accidents at Barokah Furniture include the absence of safe working SOPs, lack of personal protective equipment (PPE), risky manual work techniques, and minimal control over dust hazards. Recommended improvements include the creation of written SOPs, provision of auxiliary tools and PPE, installation of dust extraction systems, and safety training for all employees. This research is expected to serve as a reference for the company to continuously improve its occupational safety and health systems.

Keywords: OSH, FMEA, FTA, Risk

INTRODUCTION

In the era of globalization, industrial development across various sectors has experienced rapid progress. One sector that continues to evolve is the furniture industry, which plays a vital role in the economy. This industry not only fulfills the community's needs for household, office, and public space equipment but also creates employment opportunities for a large workforce. However, as production volumes increase, the potential risks to Occupational Safety and Health (OSH) also rise. Therefore, a systematic risk analysis is essential to ensure a safe and healthy working environment for employees (Amin et al., 2023).

Occupational Safety and Health (OSH) is an aspect that cannot be ignored in any industrial activity, including the furniture industry. The potential accident risks vary widely, ranging from machinery-related accidents, chemical exposure, and noise to ergonomic disorders (Annas & Putra, 2024). Without proper control, these risks can have serious impacts on both the workers and the continuity of the production process. Consequently, a risk analysis method capable of providing a comprehensive overview and appropriate mitigation steps in managing OSH risks is required (Anita et al., 2023).

One approach that can be utilized is Failure Mode and Effect Analysis (FMEA). This method is used to identify potential failures in a system or process while analyzing their impact on safety, health, and performance (Ateng et al., 2021). In the furniture industry, FMEA can be applied to evaluate risks at every production stage, from material cutting to the finishing process. In this way, potential causes of failure can be identified, the severity and probability of occurrence can be estimated, and appropriate mitigation steps can be determined (Hardiansah et al., 2023).

Additionally, this study also employs Fault Tree Analysis (FTA) as a complementary method. FTA is an analytical technique that constructs a fault tree diagram to trace the primary causes of an accident or problem (Hardiansah et al., 2023). In the context of the furniture industry, FTA enables a deeper investigation into root causes. For example, an accident involving a cutting machine can be further analyzed to determine whether the cause stems from operational factors, component failure, or unsafe working environmental conditions (Prisilia & Purnomo, 2022).

The application of combined FMEA and FTA provides a more comprehensive understanding of OSH risks in the furniture industry (Hanif et al., 2015). Through FMEA, risks can be prioritized based on the RPN value, while with FTA, the root causes of those priority risks can be explored more deeply. Thus, companies can obtain concrete recommendations, such as more scheduled machine maintenance, increased use of personal protective equipment (PPE), and safety training for workers (Simbung, 2023).

Overall, this research aims to analyze occupational accident risks in the production process at Barokah Furniture Pasuruan using the FMEA and FTA methods. The results of the analysis are expected to serve as recommendations for improving the OSH system, while supporting the creation of a safer, healthier, and more productive working environment (Hardiansah et al., 2023).

LITERATURE REVIEW

1. Occupational Safety and Health (OSH)
   Occupational Safety and Health (OSH) Occupational Safety and Health (OSH) is a system aimed at protecting workers from potential hazards that could cause accidents or health impairments in the workplace (Simbung, 2023). OSH encompasses systematic preventive efforts to create a work environment that is safe, healthy, and aligned with both the physical and psychological conditions of the workers. The implementation of OSH aims not only to prevent losses due to accidents but also to maintain the well-being of the workforce and support optimal work productivity. Thus, OSH becomes an essential element in realizing operational continuity and high-quality work (Gultom, 2022)..
2. Risk
   Risk is the possibility of an event occurring that can hinder the achievement of objectives, whether in the form of loss, danger, or unintended consequences (MUHAMMAD RAFI, 2023). Risks can arise from uncertainty, stemming from internal factors such as system weaknesses and human error, as well as external factors like disasters, supply chain disruptions, or regulatory changes. According to ISO 31000:2018, risk is defined as "the effect of uncertainty on objectives." This means risk is the result of uncertainty that affects the achievement of organizational goals. The mentioned effect can be positive or negative; however, in the context of occupational safety, risk generally refers to the potential for hazardous events that can result in injury, damage, or loss (Hardiansah et al., 2023).
3. *Failure Mode and Effect Analysis* (FMEA)
   A systematic method known as Failure Mode and Effect Analysis (FMEA) is intended to identify, analyze, and prevent potential failures within a process, product, or system before they occur (Ateng et al., 2021). This method is used to enhance quality, reliability, and safety by identifying threats and determining which corrective measures are most critical. In various sectors, such as manufacturing, automotive, and healthcare, FMEA has been utilized to improve product and

process reliability. For instance, in the automotive industry, FMEA is used to analyze potential vehicle component failures and determine necessary preventive actions (Prakoso & Sari, 2022). In the healthcare sector, FMEA helps identify risks in medical procedures and improves patient safety. The application of Failure Mode and Effect Analysis (FMEA) involves the following steps: (1) identification of process functions, (2) identification of failure modes, (3) analysis of failure effects, (4) assessment of severity, (5) identification of potential causes, (6) assessment of occurrence, (7) assessment of detection, (8) calculation of the Risk Priority Number (RPN) value, and (9) recommended actions (Wardhani & Utomo, 2023).

4. *Fault Tree Analysis* (FTA)
   This method utilizes a tree diagram to demonstrate the relationship between various events that potentially cause a primary failure, also known as the "top event." This facilitates the understanding and tracing of root causes (Sajiwo & Hariastuti, 2021). FTA has been applied across various industrial sectors to improve system reliability and security. For example, FTA is used in the aviation industry to assess the likelihood of aircraft component failures and establish preventive measures. In manufacturing, FTA helps identify the causes of product failure and improves production quality (Simbung, 2023). According to research, the FTA method was used to evaluate errors based on Ground Finding Sheet (GFS) data at PT. GMF Aero Asia. The results indicated that the FTA method could determine the primary factors causing damage to aircraft cabin sections, allowing repairs to be focused on those specific factors..

METHODOLOGY

His research employs the Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) methods. FMEA aims to identify potential failures in the production process, assess their impacts, and determine risk priorities. Meanwhile, FTA is used to analyze the root causes of failure modes with the highest risk values.

The FMEA process begins with identifying process functions and failure modes at each production stage. This is followed by an analysis of failure effects, then an assessment based on three parameters: Severity (S) for the level of impact, Occurrence (O) for the frequency of occurrence, and Detection (D) for the probability of being detected. These three values are calculated into a Risk Priority Number (RPN) using the following formula :

$$RPN = S \times O \times D$$

Description :
RPN = *Risk Priority Number*
S = *Saverity*
O = *Occurrence*
D = *Detection*

Failure modes with the highest RPN values are selected for further analysis using FTA. Through a fault tree diagram, FTA traces the fundamental causes of failure, covering aspects of human factors, equipment, and the work environment. The combined results of FMEA and FTA are then used to formulate recommendations for improving the OSH (Occupational Safety and Health) system in the furniture industry.

RESULTS AND DISCUSSION

Implementation of FMEA

This study applies the FMEA method to identify potential failure modes that could lead to occupational accident risks and their impacts within the packing division. The Risk Priority Number (RPN) is calculated by multiplying three components: severity (S), occurrence (O), and detection (D). The assessment of these components in this research was developed based on a combination of field observations, interviews with production operators, and references from general FMEA guidelines. The values for severity, occurrence, and detection for each failure mode were obtained from questionnaire results distributed to 15 employees in the production division. The questionnaire results are attached in Appendices 3 – 17. Each respondent provided a rating on a scale of 1–10 based on their respective work experience. The final value for each parameter was obtained by averaging all respondent feedback. The data was processed by calculating the mean values of S, O, and D. The determination of values for each component is explained as follows.

Based on the Risk Priority Number (RPN) table above, it is identified that the highest RPN value occurs in the sawing process, specifically cuts from saw blades. The second highest occurs during the wood cutting process to smaller sizes, namely respiratory issues due to excessive dust. The third highest is found in the wood cutting process regarding hand injuries from machine blades, as well as in the planning process, specifically contact with machine blades or planer tools. These three failure modes with the highest RPN are identified by the codes FM3, FM8, FM7, and FM9. These failure modes will be used for FTA analysis to formulate improvement recommendations and suggestions for the company.

Tabel 1. Risk Priority Number (RPN)

NO	Production Process	Failure Mode Code	Failure Mode	Cause	S	O	D	RPN	RANK
1.	Unloading Log	FM1	Being crushed by logs during unloading	Serious physical injuries such as fractures or heavy bruises.	9	4	4	144	6
		FM2	Slipping in a slippery unloading area	Falling, causing cuts, bruises, or fractures.	6	7	3	126	9
2.	Sawing	FM3	Cut by the saw blade	Severe injuries including possible amputation.	10	5	5	250	1
		FM4	Hit by flying wood chips	Eye injuries, skin irritation, or minor cuts.	5	6	2	60	17

3.	Shaping (Using Templates)	FM5	Cuts during template shaping	Minor cuts on hands or fingers	3	8	2	48	18
		FM6	Muscle strain from non-ergonomic posture	Muscle pain or chronic fatigue	4	6	3	72	14
4.	Cutting Wood Into Smaller Sizes	FM7	Hand injury from machine blade	Deep cuts or potential amputation	9	4	5	180	3
		FM8	Respiratory issues due to excessive dust	Breathing problems, eye and skin irritation	7	7	4	196	2
5.	Planning (Planer Machine)	FM9	Hit by planer blade	Luka parah seperti sayatan dalam	9	4	5	180	3

Based on the Risk Priority Number (RPN) table above, it is known that the highest RPN value occurs in the sawing process, specifically the failure mode of being cut by the saw blade. The second highest risk occurs in the process of cutting wood into smaller sizes, namely respiratory disorders caused by excessive dust. The third highest risk also appears in the wood-cutting process, involving hand injuries due to contact with the machine blade, as well as during the planning (planer) process, where workers may be struck by the planer blade. These failure modes—with the highest RPN values—are identified as FM3, FM8, FM7, and FM9, respectively. These failure modes were selected for further analysis using the

Fault Tree Analysis (FTA) method in order to formulate recommendations and improvement actions for the company.

Tabel 2. Tabel Risk Level

Severity	**1-71**	**72-391**	**392-1000**
1-6	FM4, FM5, FM11, FM13, FM19	FM2, FM6, FM12, FM14, FM17, FM18	
7-8		FM1, FM10, FM15, FM20	
9-10		FM3, FM7, FM9, FM8	

Application of FTA

Following the identification of critical risks using FMEA, the next step was conducting FTA to identify root causes of the three highest-risk failure modes. FTA diagrams (in the original document) illustrate contributing factors such as:

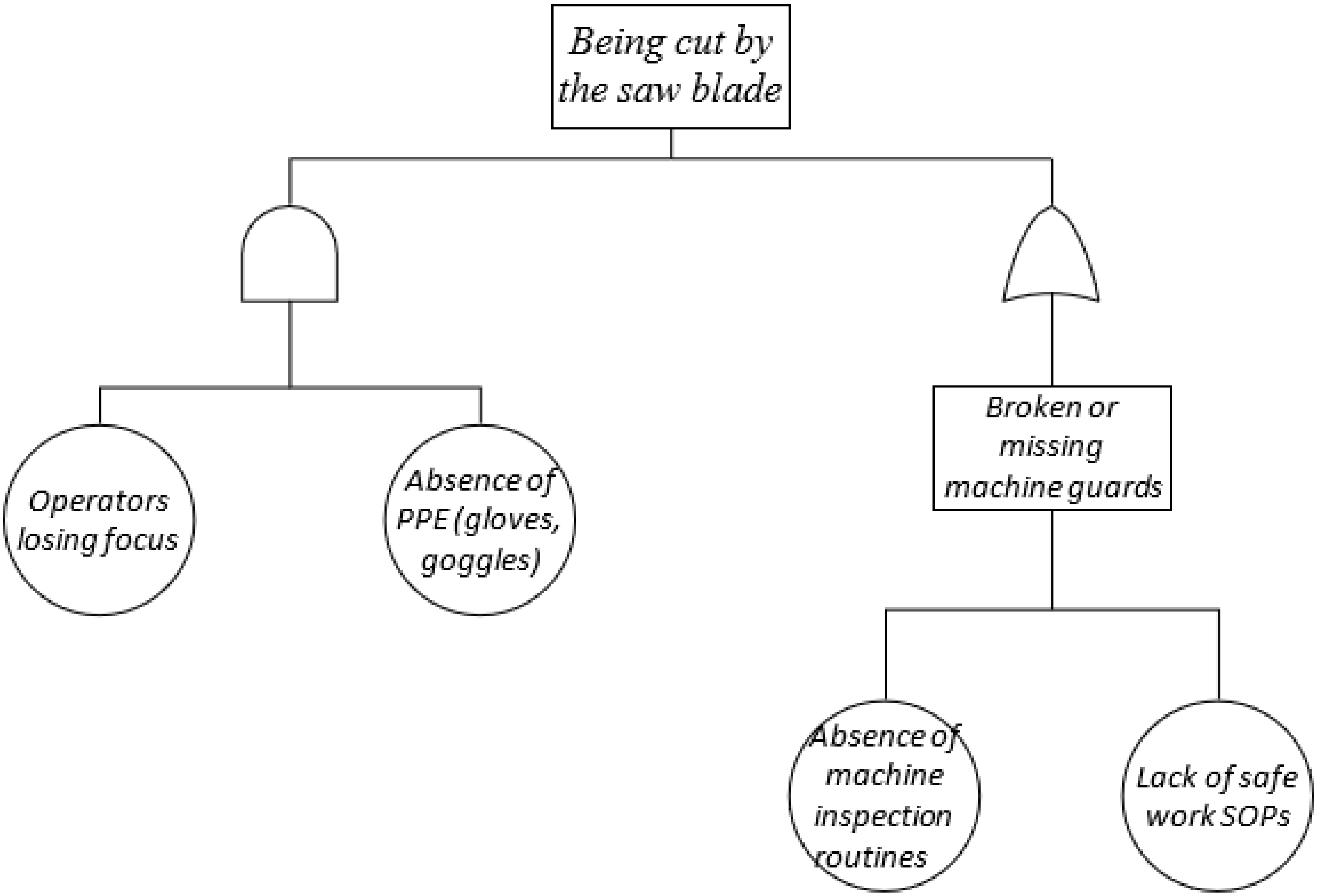

Figure 1. FTA Diagram "Being cut by the saw blade".

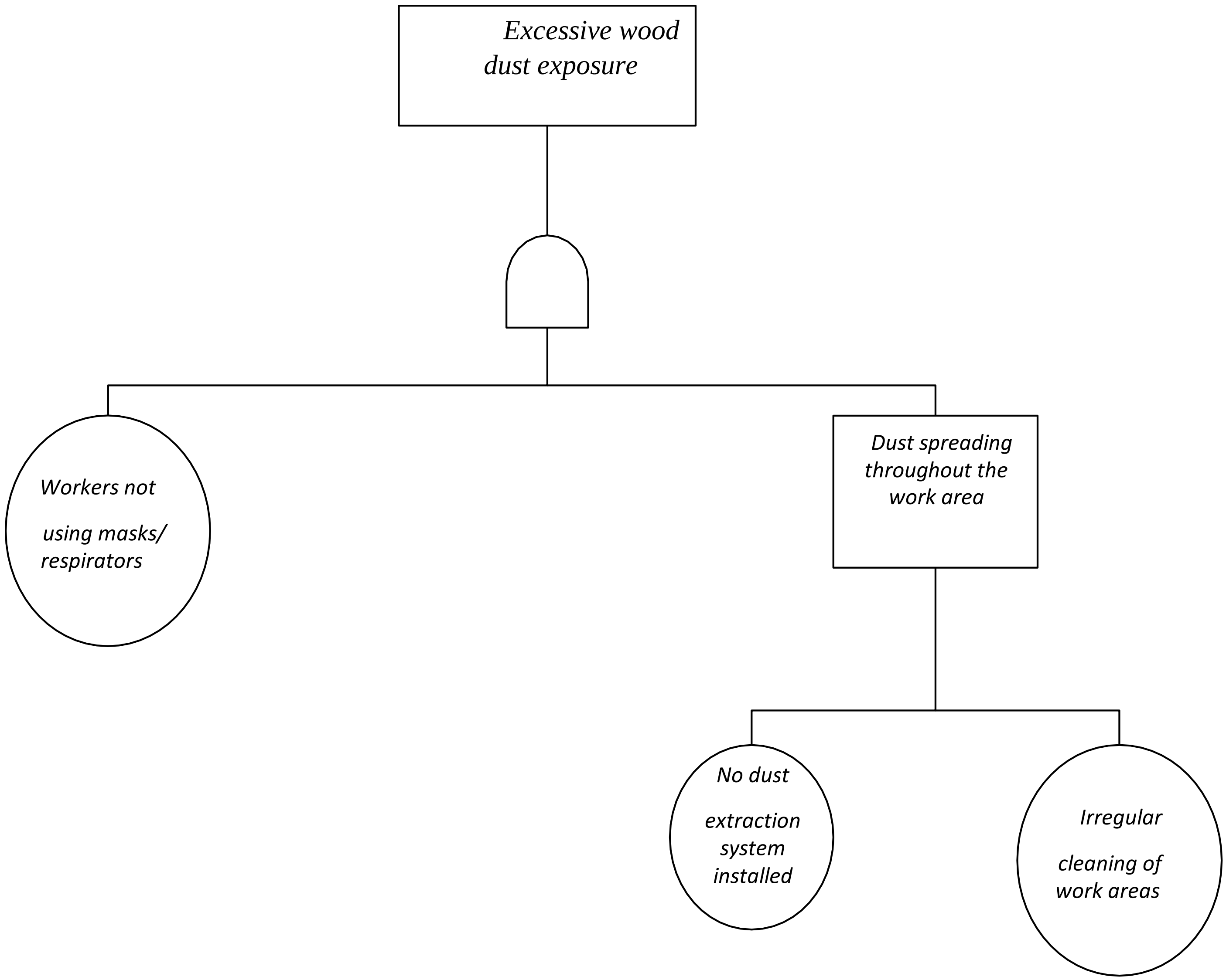

Figure 2. FTA Diagram "Excessive wood dust exposure"

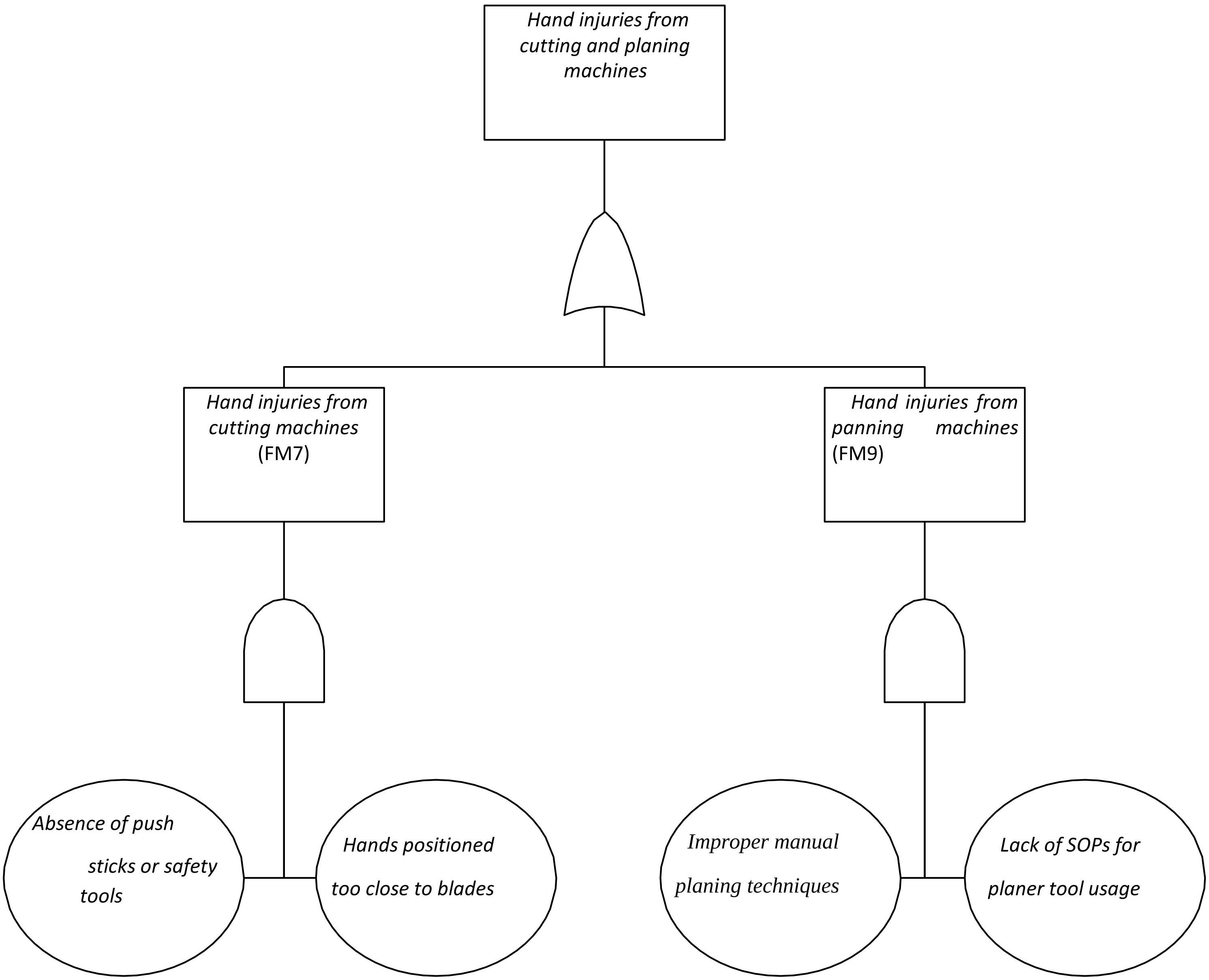

Figure 3. FTA Diagram "Hand injuries from cutting and planing machines"

Based on the results of the Fault Tree Analysis (FTA) for the three failure modes with the highest RPN values FM3 (being cut by the saw blade), FM8 (excessive exposure to wood dust), and FM7/FM9 (hand injuries caused by cutting machines and manual planers)—several basic events were identified as the primary causes of each top event. Each basic event was analyzed in order to develop specific corrective actions, both preventive and mitigative in nature.

Table 3. Improvement Recommendations

Failure Mode Code	Top Event	Intermediate Event	Basic Event	Rekomendasi

FM3	Being cut by the saw blade	Broken or missing machine guards	Absence of machine inspection routines	• Schedule regular inspections and implement a checklist for tool and machine
		-	*Lack of safe work SOPs*	• *Create and display written Safe Operating Procedures (SOPs) in the work areas*
		-	*Operators losing focus*	• *Provide safety training and apply job rotation to prevent operator fatigue*
		-	*Absence of PPE (gloves, goggles)*	• *Enforce the use of Personal Protective Equipment (PPE), such as cut-resistant gloves and safety goggles*
FM8	Excessive wood dust exposure	Workers not using masks/respirato rs	-	• Require workers to use N95 masks/respirators in sanding or dust-intensive areas
		Dust spreading throughout the work area	Irregular cleaning of work areas	• Schedule production area cleaning twice a day and assign specific cleaning personnel
		-	Pembersihan debu tidak rutin	• Jadwalkan pembersihan area produksi 2x sehari dan berikan tugas khusus petugas kebersihan
FM7, FM9	Hand injuries from cutting and planing machines	Hand injuries from cutting machines (FM7)	Absence of push sticks or safety tools	• rovide push sticks at every workbench and require their use when cutting small pieces of wood
		-	Hands positioned too close to blades	• Educate workers on safe working techniques and establish clear hand-safety boundary markings on workbenches

		Hand injuries from panning machines (FM9)	Improper manual planing techniques	• Provide training on proper manual planing techniques
		-	Lack of SOPs for planer tool usage	• Prepare illustrated written SOPs and display them in the planer workstation area

CONCLUSION

The results of the Fault Tree Analysis (FTA) on the three priority risks identified through FMEA show that workplace accidents at Barokah Furniture Pasuruan are primarily caused by both technical and behavioral factors. In the case of saw blade injuries (FM3), the main contributing factors include the absence of machine guards, the lack of safe work procedures (SOPs), and reduced operator focus. The risk of excessive wood dust exposure (FM8) is mainly caused by the absence of a dust extraction system, failure to use appropriate respiratory protection, and poor housekeeping practices in the work area. Meanwhile, the risks of hand injuries caused by cutting machines and manual planers (FM7 and FM9) are influenced by unsafe working techniques, lack of SOPs, and the absence of supporting tools such as push sticks.

Based on these findings, it is recommended that the company develop and enforce written safe work procedures, provide appropriate personal protective equipment (PPE) such as masks, gloves, and goggles, install dust extraction systems, and supply necessary work aids. In addition, regular training and machine inspections must be carried out to reduce the likelihood of accidents resulting from both human error and technical failures. Strengthening these preventive measures is expected to enhance the overall occupational safety and health (OSH) system and support a safer and more productive working environment.s.

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