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Identification of Factors Causing Wood Defects in Furniture Product Material (Flooring) Using the Fault Tree Analysis Method at PT. ABC

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ABSTRACT

PT. ABC is a manufacturing company specializing in the production of teak wood products, including flooring. To ensure the production of high-quality products, PT. ABC implements quality control measures, starting with the identification of product defects to minimize process errors. The goal of this research is to identify product defects at PT. ABC and determine the root causes of these defects using the Fault Tree Analysis (FTA) method. Additionally, the study aims to provide improvement suggestions for preventing and reducing potential causes of product defects. The results of this research indicate that the main defect is related to incorrect dimensional size. During product sampling within the initial 180 minutes of the production process, the probability of incorrect size is 15.69%, followed by lumps with a probability of 11.21%, and rough surface with a probability of 8.20%. Areas requiring improvement include: 1. Workforce: Skilled and disciplined personnel are needed to follow procedures and equipment specifications in the flooring production process at PT. ABC; 2. Process: Maintenance activities should be enhanced, and regular checks should be conducted as necessary.

Keywords: Zero defect, flooring, maintenance, fault tree analysis

Introduction

The common challenges faced by many manufacturing industries in Indonesia for companies to survive in the increasingly competitive business environment include the production of imperfect or non-defect-free products, as well as the need for companies to assure consumers that the products they produce are of high quality (Susetyo et al., 2022). Essential to establish rigorous product supervision to be implemented as an assurance to consumers that the products released to the market are of high quality (Sun et al., 2022). The company's quality management is oriented towards continuously striving to improve quality dramatically, ultimately aiming for zero defects (Masalegooyan et al., 2022). PT. ABC is a manufacturing company involved in the production of various finished products and raw wood materials. To ensure the production of high-quality products, PT. ABC initiates quality control by first identifying defects in the raw materials to minimize process errors as much as possible. Percentage of defects in the raw materials during the production process at PT. ABC has been approximately 5%. This percentage is calculated based on the production results for one month, which yielded a total of 10,200 floorings, with 490 floorings found to be defective. These changes lead to preventive efforts that continue to be developed sustainably and ultimately lead to the application of the principle of clean production (Fathurrahman et al., 2022). The company is required to maintain product quality by ensuring stable output that meets specifications and competitive pricing (Hidayat, 2021).

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One of the factors is the development of competent human resources to produce products that meet industry standards (Yolanda et al., 2023). Quality is the overall features and characteristics of a product or service that support its ability to satisfy customer needs (Sunaryo & Hamka, 2019). The factors causing defective products in manufacturing companies include human error, raw material quality, equipment malfunction, and inadequate quality control (Analysa et al., 2019). The common defects that frequently occur in the production process at PT. ABC is related to the form factor. These defects include dimensions not being to specifications, compacted products, and rough surfaces. These types of defects are often caused by malfunctioning machinery or incorrect machine settings. This research will adopt a quality improvement method known as Fault Tree Analysis (FTA). This method can be used to analyze various causes of errors, which are presented in a fault tree, and calculate the probability of the top event occurring based on event reliability predictions (Duyo, 2020). It also utilizes the cut-and-tie set method to evaluate the probability of errors in the production system. The utilization of the FTA method will enable the identification of product defects occurring at PT. ABC by determining the root causes of defects based on defect data recorded by the Quality Control (QC) department. This will help in achieving high product quality and the company's goal of producing products that meet consumer demands.

The purpose of this research is to identify defects in flooring materials and the factors causing these defects and determine the probability of product defects occurring during the production process at PT. ABC, provides improvement recommendations for preventing and reducing potential causes of defects in raw materials. By implementing the Fault Tree Analysis (FTA) method, it is hoped that the company can reduce the number of product defects it has experienced thus far. This method can serve as a tool for the company to continuously improve the products it produces, demonstrating the company's commitment to maintaining product quality standards to satisfy consumer preferences. This method is used to identify problems that begin with detailed assumptions about events at the top until the root causes of the fundamental issues can be determined (Wicaksono et al., 2022). This method is top-down, which means it starts with assumptions about failures at the top event and then details them down to the basic failures (Moh et al., 2023).

Literature Review

Quality control

The term "quality" is indeed intertwined with quality management, which encompasses every aspect of operations management, from product and facility planning to scheduling and monitoring outcomes (Prasmoro et al., 2021). Quality is an integral part of all other business functions, including marketing, human resources, finance, and more. It emphasizes the importance of ensuring that products, services, and processes meet or exceed established standards and customer expectations in every aspect of an organization's activities (Yusuf et al., 2020). Quality requires an ongoing process of continuous improvement that can be measured at the individual, organizational, corporate, and national performance levels (Pradana Assagaf et al., 2023). Quality improvement is more than a business strategy, a personal responsibility for every company. Commitment to quality is an attitude that is formulated and demonstrated in every aspect of business and life and has the closest relationship with the community (Sun et al., 2022).

The concept of quality must be comprehensive, encompassing both the product and its processes. Product quality includes the quality of raw materials and finished goods, while process quality involves everything related to the manufacturing process in manufacturing companies and the service delivery process in service-oriented businesses (Syahabuddin & Zulziar, 2021). Quality should be built from the outset, from the reception of inputs to the production of outputs for the customers (Nugraha & Sari, 2019). The goal of quality control is to ensure that the quality of the products produced meets the defined quality standards at an economically viable cost. This means maintaining consistent quality while optimizing costs to achieve an efficient and competitive production process (Susetyo et al.,

2022). Even though Quality Control measures have been implemented for raw materials and the production process, this does not guarantee that there will be no defective or subpar outcomes. Despite all efforts to ensure quality, unforeseen factors or process variability can still lead to defective or subpar products (Fathurrahman et al., 2022).

Inspection is a way to determine the extent to which a product meets the desired quality standards. The information obtained through inspection is then communicated to other departments, which assure that the activities in the process have been carried out properly (Hidayat, 2021). However, if there are deviations, a warning is issued to initiate corrective action, and further production activities are halted. This process helps maintain and improve product quality throughout production (Yolanda et al., 2023).

Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is an analysis method used to determine the potential root causes of a failure within a system, enabling efforts to reduce defective products (Prasmoro et al., 2021). It is a systematic approach to identifying and analyzing the causes of failures or defects, which can help in developing strategies to prevent or mitigate these issues and enhance the overall quality of the products or processes (Yusuf et al., 2020). In addition to demonstrating the logical relationships between events leading to the occurrence of a top event, FTA is also used to quantify the probability of the top event (Moh et al., 2023). The probability of failure is obtained from reliability predictions for the failure events. It's worth noting that different FTAs must be constructed for each top event caused by different failure patterns or logical relationships between different failure events (Pradana Assagaf et al., 2023). This approach allows for a more detailed and specific analysis of different failure scenarios (Sun et al., 2022).

With its nature, the fault tree also reveals a cause-and-effect analysis pattern similar to what is found in a fishbone diagram. Because the fault tree also illustrates the cause-and-effect relationships of product failures, it is often referred to as Failure Mode and Effects Analysis (FMEA) (Masalegooyan et al., 2022). Fault Tree Analysis provides an analytical opportunity to identify various causes of errors by applying a deductive approach based on the principles and rules that have been outlined (Nugraha & Sari, 2019). In the execution with the second object, the causes of errors are presented using a fault tree. This method allows for a structured and systematic examination of the factors contributing to errors or failures within a system or process (Syahabuddin & Zulziar, 2021). As mentioned, the fault tree is not a model of all failures occurring in a system. In reality, it represents a logical model of interactions between events that lead to an undesired outcome (Duyo, 2020). Fault trees are a tool used to understand and analyze the interplay of different events and conditions that can result in a specific failure or undesirable event within a system or process. They provide a structured way to assess and address the causes of potential failures (Yolanda et al., 2023).

Material and Methods

This study uses the Fault Tree Analysis (FTA) study method, identifying top events or primary failure/incident events based on the analysis of production defect data recorded by the Quality Control department. The next step is to identify the causes and root causes of the Top Event through primary and secondary causes. This is done through brainstorming sessions with employees who are involved in operations at each workstation. Determining defects down to their root causes and representing them in a fault tree diagram, along with logic symbols for these root causes, is a process that helps trace the causes of undesirable events or failures that need to be avoided. The fault tree diagram is a visual tool used to systematically map out the logical relationships between these causes, leading to

the undesired event or failure. It allows for a structured analysis of how various factors contribute to the top event and helps in developing strategies for prevention and improvement.

Next, the evaluation is carried out using the Cut Set Method to obtain more specific insights into the defects. The Cut Set Method is a technique used in fault tree analysis to identify specific combinations of events or conditions that lead to the undesired event or failure. It helps in narrowing down the potential causes and provides a more detailed understanding of the specific defects or failure modes. After the evaluation, the probability of failure causes is calculated to determine the extent of defects and their impact on the company in the future. This involves assessing the likelihood of each identified cause contributing to the undesired events and understanding the overall impact on the company's operations and performance. It helps in quantifying the level of defects and their potential consequences, which is crucial for making informed decisions and improvements.

Results and Discussion

The penalty for paying compensation is a consequence of deceit or corruption that endangers the country's finances or the country's economy. A Juridical means is needed to recover the losses, namely in the remittance of replacement money. Replacement money is an additional form of punishment (criminal) in corruption cases. In essence, both legally and doctrinally, judges are not required to always impose additional penalties.

Identify the top event of defects

Based on the data on product defects provided by the Quality Control department, the top events of defects can be identified. These defects include:

1. Incorrect dimensional size
2. Lumps
3. Rough surface

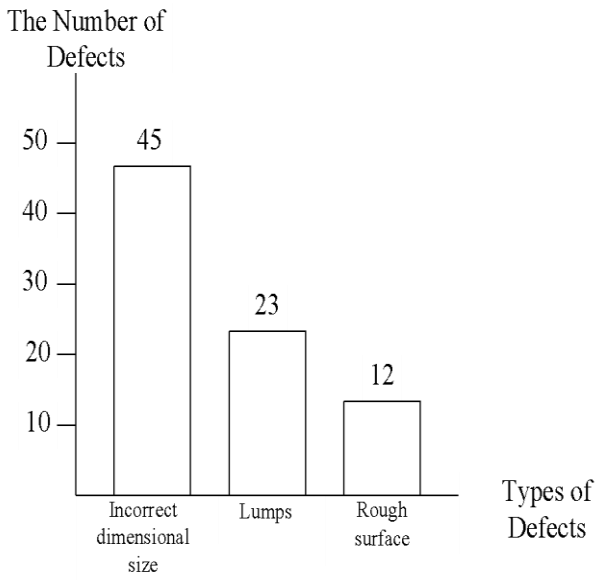


Figure 1. Defect product histogram

Based on this defect data, a product defect histogram can be created to visualize the occurrence of defects in the company.

Based on the above histogram, the percentage of defective products that occurred during one week of production can be determined in the following Table 1.

Table 1. Percentage of defective products during one week of production

No	Type of Defect	Number of Defects	Defect Percentage (%)	Cumulative Number of Defects	Cumulative Defect Percentage (%)
1	Incorrect dimensional size	45	$\frac{45}{2394} x100\% =$ 1,879	45	1,879
2	Lumps	23	$\frac{23}{2394} x100\% =$ 0,960	68	2,839
3	Rough surface	12	$\frac{12}{2394} x100\% =$ 0,501	81	3,340

Identify the causes of the top event

The causes of dimensional incorrect dimensional size, lumps, and rough surface can be identified through primary and secondary causes, as indicated in Table 2.

Table 2. Causes of Incorrect Dimensional Size, Lumps, and Rough Surface

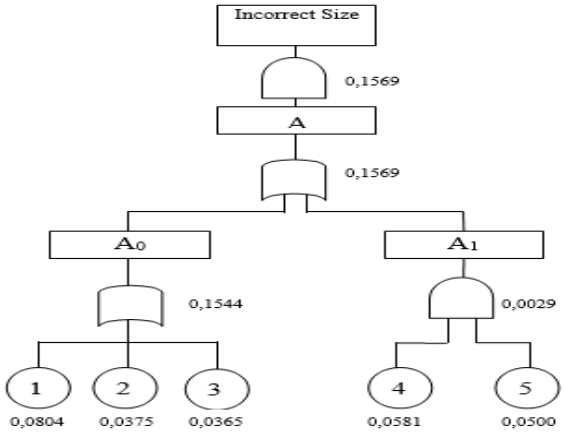
Product Defects (Top Event)		Primary Cause		Secondary Cause
Incorrect dimensional size	1	The rolling machines and supporting machines are not performing at their maximum capacity.	1	**Machines:** The new production process is running a. Setting mesin kurang presisi **Human Factors:** a. Operators are in a hurry. b. Operators lack skill.
			2	**Machines:** A problem occurred while production was running a. Machine trouble b. Machine caliber is worn/damaged
Lumps	1	Machine capacity is not at its maximum	1	**Machines:** The new production process is running. a. Machine is dirty.
			2	**Machines:** The machine Caliper Rolling is worn/damaged. a. The cutter usage has reached its maximum. **Environment:** a. Poor cooling water.
Rough surface	1	Machine capacity is not at its maximum	1	**Machines:** The new production process is underway. a. Machine settings are less precise. **Human Factors:**

To be continued…

Product Defects (Top Event)	Primary Cause	Secondary Cause
		a. Operators are in a hurry. b. Operators lack skill.
		2 **Machines:** Cutter block caliper is worn/damaged. a. Cutter block usage has reached its maximum. b. Incorrect installation of the cutter block.
	2 The FSM machine caliper is worn/damaged	1 **Machines:** FRR usage is at its maximum. a. The quality of FRR rolls is not good. b. The machine is dirty.
		2 **Machines:** Improper installation of the FRR caliper. a. The caliper design is not suitable. **Human Factors:** a. Operators lack attention to detail

Fault Tree Analysis (FTA)

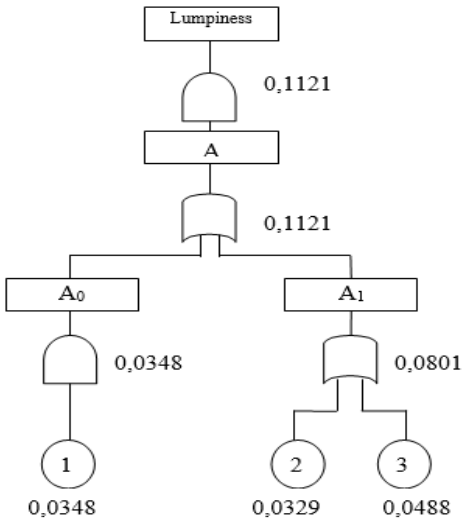
The calculation of defect probability is based on the fault tree diagram before the evaluation with the cut set. Therefore, the calculation starts from the bottom, which is the probability of the root causes of an event. Calculating the probability of the event of incorrect dimensional size begins from the root causes at the bottom and proceeds upwards.



Information: A: Rolling machine and supporting machine capabilities are not at their maximum; A0: New production process is underway; A1: Issues occur during production; 1: Machine settings are not precise; 2: Operators are in a hurry; 3: Operators lack skill; 4: Machine trouble; 5: Machine caliper is worn/damaged.

Figure 2. Probability of incorrect dimensional size

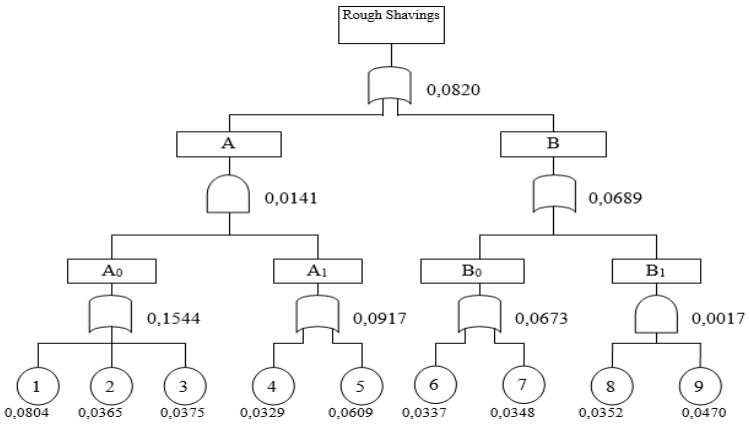
The probability calculated after the evaluation is 0.1573 or 15.73% for the initial 180 minutes of the production process. Meanwhile, the probability before the evaluation was 0.1569 or 15.69%. These probabilities indicate that the occurrence of the incorrect dimensional size defect is far from 1 and even less than 0.5, categorizing it as a frequently occurring event.



Information: A: Machine capacity is not at its maximum; A0: The new production process is running; A1: The Rolling machine caliper is worn/damaged; 1: The machine is dirty; 2: The cutter usage has reached its maximum; 3: Poor cooling water

Figure 3. Probability of lumps

The probability calculated after the evaluation is 0.1165 or 11.65% for the initial 180 minutes of the production process. Meanwhile, the probability before the evaluation was 0.1121 or 11.21%. These probabilities indicate that the occurrence of the "Lump" defect is far from 1 and even less than 0.5, categorizing it as a frequently occurring event.



Information: A: Machine capacity is not at its maximum; A0: The new production process is running; A1: The Cutter block caliper is worn/damaged; B: The FSM machine caliper is worn/damaged; B0: The usage of FRR is at its maximum; B1: Inaccurate installation of the FRR roll caliper; 1: Machine settings are not precise; 2: Operators lack skill; 3: Operators are in a hurry; 4: Cutter usage has reached its maximum; 5: Cutter installation is inaccurate; 6: The quality of the FRR roll is not good; 7: The machine is dirty; 8: The caliper design is not suitable; 9: Operators lack skill

Figure 3. Probability of Rough Surface

The probability calculated after the evaluation is 0.1124 or 11.24% for the initial 180 minutes of the production process. Meanwhile, the probability before the evaluation was 0.0820 or 8.20%. These probabilities indicate that the occurrence of the "Rough Surface" defect is far from 1 and even less than 0.5, categorizing it as a frequently occurring event.

Correction action

So, of the three types of defects that need to receive attention and make improvements to the production system are the events that form the event of incorrect dimensional size. Proposed improvements made by using correction actions for these events to control the course of the production process can be shown in Table 3.

Table 3. Correction Actions for Incorrect Dimensional Size

Root Cause	Probability	Description of Condition	Correction Action	Corrected (Addressed) Area
Imprecise Machine Setup	0,0804	The imprecision in machine setup often occurs at the beginning of the production process because of operators who lack precision when operating the machine, settings that are based solely on the operator's visual or instinct, and due to the limitations of the available equipment.	To make the initial machine setup more precise, it requires skilled personnel who are disciplined in following established procedures in line with the equipment available in the flooring production process at PT. ABC.	Labor
Operators are in a hurry	0,0375	The presence of daily production targets and tight deadlines set by the company makes each operator very busy with their activities, leading them to appear rushed in their operations. This can result in the production process not following the procedures correctly and the products not meeting the standards set by the company.	It is advisable for the leaders of each workstation to pay more attention to the workers/operators. They should not pressure the operators to finish as quickly as possible but provide motivation rather than pressure, so the operators work without rushing and follow the procedures more effectively.	Labor

To be continued…

Root Cause	Probability	Description of Condition	Correction Action	Corrected (Addressed) Area
Operators lacking skills	0,0375	In addition to operators rarely paying attention to the production process procedures, they also lack skills, especially in the process of producing flooring, particularly when it comes to setting up machines, which requires different techniques and methods compared to the production processes of other wooden flooring products such as listoni or lam parket, as the equipment/machinery used is different.	PT. ABC should consider providing training, specifically tailored to the needs of the workers at their respective workstations. This training should focus on improving the skills required to address potential issues that may arise during the production process.	Labor
Machine trouble	0,0581	This is because the machines operate continuously 24 hours a day, and maintenance, especially preventive and predictive maintenance, is lacking.	Maintenance improvement is needed, and if necessary, checks should be performed at all times. This will help minimize issues related to machine failures in the production process.	Maintenance in the Rolling Process
Machine caliber worn out/damaged	0,0500	The quality of rolls or cutters used is not as expected, and the calibration/design setting is not suitable.	Inspection of the quality of rolls, roll caliper design, and cutter blocks to be used is required so that the machine's capability can work optimally.	Rolling Process

Conclusion

The conclusion of this study is as follows:

1. The most common types of defects in flooring are Incorrect dimensional size, Lumps, and Rough surfaces. The factors that frequently cause product defects are related to machine, human (operator), and work method factors.
2. The probability of a defect occurring in PT. ABC's products is as follows:

a. Incorrect dimensional size: The probability of an event occurring in the first 180 minutes at the beginning of the production process is 0.1569 or 15.69%.
b. Lumps: The probability of this event occurring in the first 180 minutes at the beginning of the production process is 0.1121 or 11.21%.
c. Permukaan serut kasar: The probability of this event occurring in the first 180 minutes at the beginning of the production process is 0.0820 or 8.20%.

Recommendations for improvement for the company, based on the Correction Action, should focus on the defect type with the highest probability, which is the defect related to the incorrect dimensional size. The areas that require corrective actions include:

1. Human Resources: Skilled and disciplined personnel are required to execute the procedures according to the available equipment in the flooring production process at PT. ABC.
2. Process: Maintenance actions should be improved, and regular checks, if necessary, should be conducted to ensure the equipment functions optimally.

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