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The Recommendations to Improve Quality of Kitchen Set Products Using New Failure Mode and Effect Analysis and Fault Tree Analysis Methods at a Furniture Company in Bandung

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Abstract. The company had a problem regarding product quality, especially on kitchen set products. Based on data for the last six months, reveals a consistent surpassing of acceptable limits for product defects every month. This causes negative consequences, encompassing both time and cost setbacks, along with a decline in consumer confidence in the company. Therefore, there was a compelling necessity to enhance the overall quality of the products. Two methodologies, New FMEA and FTA, were used to pursue the objective. A New FMEA was used to indicate which type of defect will be prioritized (using Action Priority (AP)) and a FTA was used to identify the root cause. The process of creating a kitchen set involved 11 steps, with defect occurrences noted in 8 of these steps. Based on AP high criteria, there were 6 failure modes (from 20) that will be singled out for root cause analysis through FTA. Based on the FTA, 14 root causes require attention. The proposed recommendations involved training, material inspection, material protection, periodic maintenance, operational procedures, replacement of measuring tools, and redesign of the workstation environment. Simulations were carried out to compare before and after (if the recommendations are applied) of AP by changing the occurrence and detection values. The simulation showed a decrease in the AP classification from high to moderate, suggesting a positive impact on product quality.

1 Introduction

Quality represents a condition encompassing individuals, procedures, goods, and the environment, all aligning with human expectations [1] . Gasperz [2] defines quality as the attributes and traits of a product capable of fulfilling consumer needs. Good quality not only ensures consumer satisfaction but also fosters a positive company reputation. To achieve a good quality involves various factors, from design to quality control. Quality control represents a methodology/system/activity that is executed continuously to uphold product standards or quality[3,2]. Quality control involves an inspection and measurement of product

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quality using inspection equipment and some procedures [4]. Inspection plays an important role as a basic operation and one of the earliest aspects of quality control, it also helps to gain information of product quality [4].

Assauri [5] describes inspection as a control activity that has been and is being performed to ensure it aligns with predetermined expectations and plans. Inspection is performed in various times, such as incoming inspection for raw materials and components, during the manufacturing process, and final inspection at the end of the manufacturing process [4]. The purpose of the inspection is, of course, to ensure that products conform to standards, with the ultimate aim of enhancing product quality and reducing defective products.

CV. X is a furniture company and one of its products is a kitchen set. On average, CV.X produces 40 kitchen sets every month. Over the past six months, the company has grappled with quality issues related to this product. The level of non-conformity of the kitchen set products consistently surpasses the company's tolerance limit (which is 5% for each process operation) every month. Mostly, inspections are carried out at the end of the production process, leading to oversight of defects that may have gone unnoticed from the beginning. The company's prevailing approach to address this issue has been either to dispose of the product (reject) it if cannot be rectified or to undertake rework if it remains repairable. Both of these actions can undoubtedly have detrimental consequences in terms of time, cost, and consumer trust due to delays in product delivery. Overall, the current company's quality control is not optimal. The company needs to improve its current quality control to minimize losses to the company.

2 Method

2.1 Data Collection

The data needed for this study are as follows:

1. Product Manufacturing Process
   At this stage, the process of making kitchen set products from raw materials to finished products is identified.
2. Production Volume
   Production volume is needed to provide information regarding production data per period which can help determine the percentage of nonconformities for each process.
3. Quantity and type of nonconformity
   The quantity and type of nonconformity will be used to calculate the nonconformity percentage for each process. Should this percentage surpass the company's standard limit (which is 5%), an assessment will be conducted using the FMEA methodology.

2.1.1 New Failure Mode Effect and Analysis (New FMEA)

Failure Mode Effect and Analysis (FMEA) is a method for identifying and prioritizing potential failures in systems, designs, processes, and services [6,7]. Additional to Carlson [8], FMEA establishes preferences for critical issues which investigates the possible ways a system could fail and evaluates the potential consequences of those failures [9].The phases of FMEA data processing are as follows [7] :

1) Identified Failure Mode
   The failure mode is determined by the type of nonconformity in each production process.
2) Identifies Failure Effect
   At this phase will determine the consequences of the failure mode.

3) Identifies Cause of Failure
   At this phase will determine the causes of failure modes
4) Identifies Current Control
   At this phase will identify the existing measures and procedures to detect failure modes
5) Determine severity, occurrence, and detection rating
   The ratings for severity, occurrence, and detection based on [7] $category$. are customized to align with the specific conditions of the company. These ratings are established through discussions with the company. Severity assesses the extent of the effect of the failure. Occurrence evaluates how frequently failure modes are likely to happen, while detection evaluates the effectiveness of the current control process
6) Determine Risk Priority Number (RPN)
   The calculation of the Risk Priority Number (RPN) is performed using the subsequent formula
   RPN = Severity x Occurrence x Detection (1)

AIAG & VDA [10] have introduced the concept of Action Priority (AP). The AP will help to categorize RPN values into three categories: High (H), Medium (M), and Low (L). Utilizing AP brings about a distinct in the New FMEA. In this study, the selected priority is High for the AP category.

2.1.2 Fault Tree Analysis

Fault Tree Analysis (FTA) is a deductive technique employed to identify system damage by representing it through a structured block diagram [11]. FTA uses a top-down analysis approach, which focuses on the effects of failures that are closely connected to the primary event [12]. This method is effective in finding the core of the problem. There are six symbols used in the FTA diagram [13]. The outcomes of the FTA will be used as a basis for determining improvement recommendations.

2.2 Simulation

The simulation was performed under the assumption of changes that could occur when implementing the recommendations for failure mode categorized as AP high (H). These alterations involve adjustments in occurrence and detection rating, considering that implementing the proposal would proactively impact the ability to identify failures sooner. If failures persist, the consequences will remain unchanged.

3 Result and Discussion

3.1 Required Data

3.1.1 Product Manufacturing Process

Four components are needed to make a kitchen set, such as hinge iron, handle iron, wood, and glass. There are 11 steps to make a product which can be seen in Figure 1.

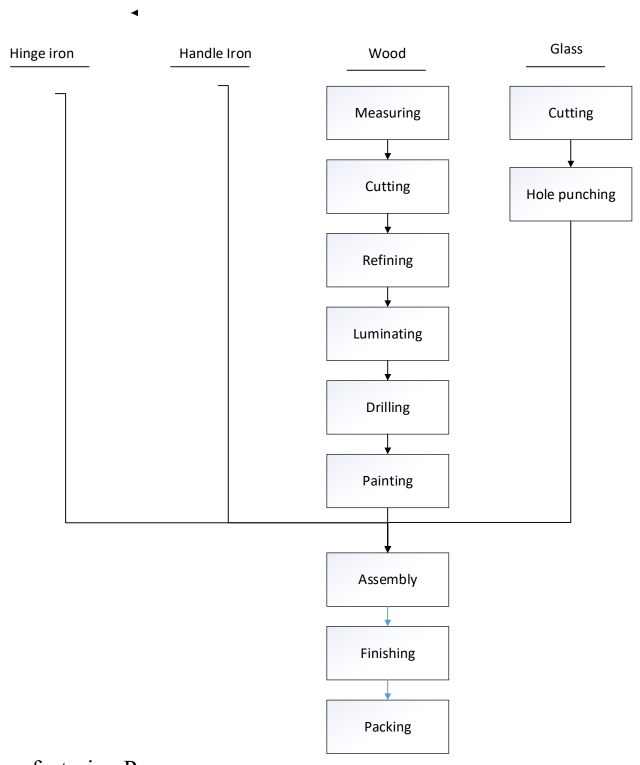

Fig. 1 Kitchen Set Manufacturing Process

3.1.2 Production Volume

Based on data collected from the company's record, during the last six months, the total production was 238 products. From this data, an average monthly production rate of 40 products.

3.1.3 Quantity and Type of Nonconformities

The quantity and type of nonconformities can be seen in Table 1. Table 1 shows there are seven processes exceeding a nonconformity rate of 5%, which aligns with company standards. These processes include wood cutting, wood refining, wood laminating, wood drilling, wood painting, glass cutting, and glass hole punching. These seven processes were selected for risk assessment using the New FMEA method, along with the application of the FTA method to identify the root cause problem.

Table 1. Quantity and Type of Nonconformities

Num.	Process	Defect (nonconformity)	nonconformity quantity	nonconformity presentation (%)
1	Wood measuring	-		
2	Wood cutting	the wood's size below standard	14 (from 40)	35
		Broken wood		
		Uneven surface		
3	Wood Refining	The wood's surface lacks uniformity and smoothness.	5 (from 40)	12.5
		Scratches on the wood		
		The wood thickness is insufficient (too thin)		
4	Wood Laminating	The laminate doesn't adhere perfectly.	6 (from 40)	15
		Bubbles on the surface of the laminate		
5	Wood Drilling	The hole is not correctly positioned.	7 (from 40)	17.5
		The hole diameter is too large		
		The hole's depth is excessively deep.		
6	Wood Painting	The paint surface is uneven	5 (from 40)	12.5
		The paint is peeling off		
		Dirt on the paint surface		
7	Glass cutting	Broken glass	13 (from 40	32.5
		Shattered glass.		
		Scratches on the glass.		
8	Glass Hole Punching	The hole is not correctly positioned.	10 (from 40)	25
		Shattered glass.		
		Cracks on glass		
9	Assembly	A broken part during the assembly process	1 (from 40)	2.5
10	Finishing	-	-	-
11	Packing	-	-	-

3.2 Data Processing

3.2.1 Risk Assessment Using New FMEA

Data processing using New FMEA adheres to the outlined procedures in the methodology section. Nonconformity type will be used as the failure mode, which in total there are 21 failure modes from the seven selected work processes. Each failure mode will have its effect categorized as either reject or rework as detailed in the failure effect category. The causes of failure were also identified and there were 46 causes of failure. The occurrence, severity, and detection values were determined through discussion with the company. The result of risk assessment using the New FMEA method can be seen in Table 2.
Table 2 shows there are six failure modes with a High category of AP, namely:

1. Shattered glass on glass cutting process
2. Broken glass on glass cutting process
3. The wood's size is below standard on the wood cutting process
4. Crack on glass-on-glass hole punching process
5. Broken wood on the wood cutting process

6. Shattered glass on the glass hole punching process.

3.2.2 The FTA method will be used to identify the root cause of the problem for these six failure modes. *Identifies Root Cause of Problem Using Fault Tree Analysis (FTA)*

The analysis of the fundamental issue behind FTA involved investigating six failure modes categorized as AP high. Therefore, Six FTAs were developed to address each of these failure modes. The following is an example of an FTA for failure mode shattered glass on glass cutting process which can be seen in Fig. 2.

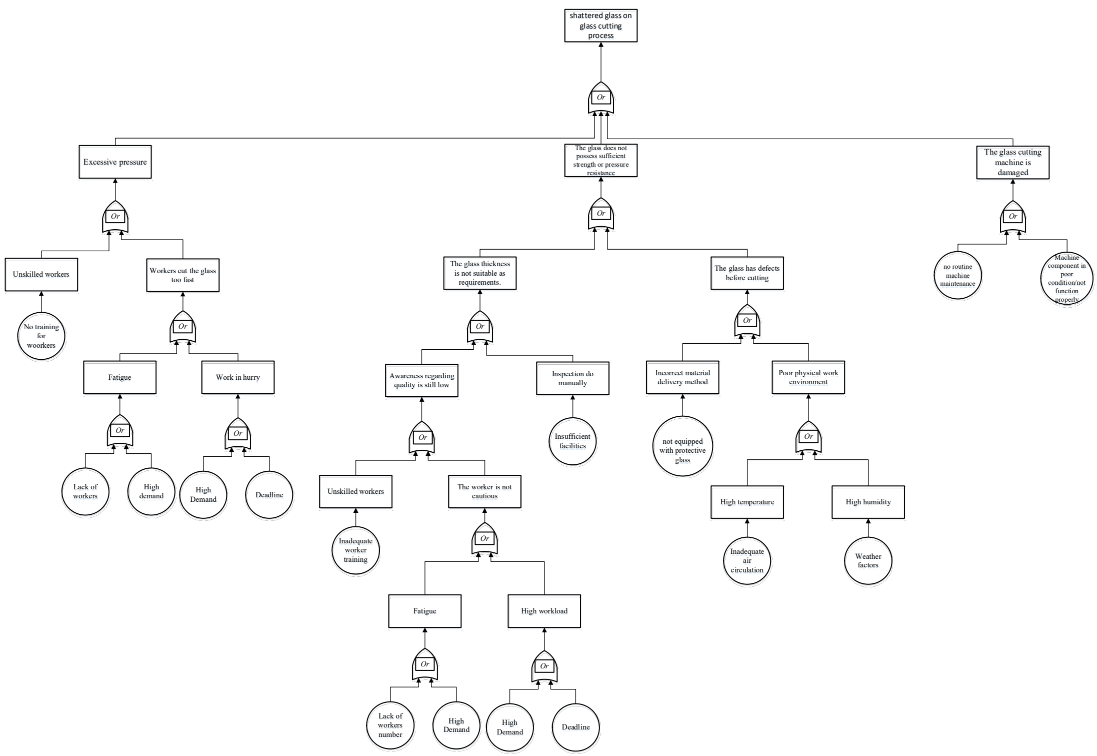

Fig. 2 Fault Tree Analysis for Failure Mode Shattered Glass on Glass Cutting Process

Figure 2 shows that the root causes of the failure mode of shattered glass on the glass cutting process are: inadequate worker training, lack of worker numbers, high demand, deadline, inadequate air circulation, weather factors, no routine machine maintenance, and machine component in poor condition or not functioning properly. According to all FTAs, the root of the problem and the recommendations can be seen in Table 3

Table 2. Risk Assessment by FMEA and Categorize Priority by AP

No	Process	Failure Mode	Failure Effect	Cause Of Failure	Current Control	S	O	D	RPN	AP
1	Glass Cutting	Shattered glass.	need to replace with new raw materials (reject classification)	1. Excessive pressure 2. The glass does not possess sufficient strength or pressure resistance. 3. The glass cutting machine is damaged	Supervising the workers	10	7	7	490	H
2	Glass Cutting	Broken glass	need to replace with new raw materials (reject classification)	1. The glass thickness is inadequate 2. Error in cutting technique	Supervising the workers	9	7	7	441	H
3	Wood Cutting	the wood's size below standard	need to replace with new raw materials (reject classification)	1. the equipment is insufficient 2. Error during the machinery operation	Supervising the workers	8	7	7	392	H
4	Glass Hole Punching	Cracks on glass	need to replace with new raw materials (reject classification)	1. Error during the machinery operation 2. Ignoring the glass temperature	Supervising the workers	9	6	7	378	H
5	Wood Cutting	Broken wood	need to replace with new raw materials (reject classification)	1. The wood that used is dry/moist 2. Error during the machinery operation	1. Supervising the workers 2.Provide knowledge about suitable raw materials	8	6	5	240	H
6	Glass Hole Punching	Shattered glass.	need to replace with new raw materials (reject classification)	1. Wrong drill bits 2. Error during the machinery operation 3. The glass hole punching machine is damaged	Supervising the workers	10	3	7	210	H
7	Wood Drilling	The hole is not correctly positioned.	replace with new materials if the hole position does not alight with the specified requirements reject classification)	1. Error when determining the hole point 2. Error during the machinery operation	Supervising the workers	8	4	6	192	M
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21	Glass Cutting	Scratches on the glass.	the scratches can be removed using chemical glass scratch removal liquid (rework classification)	Error during the machinery operation	Supervising the workers	2	2	4	16	L

Note : S = Severity, O = Occurrence, D = Detection, RPN = Risk Priority Number, AP = Action Priority

Table 3. Summary of Root Cause of Problem and Recommendations

No	Root Cause	Recommendations
1	No training for workers	Providing specialized training for operators to enhance their skills and knowledge in carrying out their tasks optimally. This training is designed to address competency gaps and improve operational efficiency. During this training, operators will receive in-depth knowledge about relevant equipment, the manufacturing process, and an understanding of the standard operational procedures
2	Lack of worker number	Further research is required concerning the workload distribution and workforce assessments. If there's a requirement for extra personnel, decisions will be made based on the findings of the study.
3	High demand	These two aspects are related. The company presently lacks a production scheduling system, so tasks are frequently executed based on their urgency rather than following a specific sequence. The company can consider starting to implement a production scheduling system
4	Deadline	
5	Insufficient equipment / facilities	Some processes are currently done manually or the tools are not updated enough. The company may want to consider to use the equipment that can facilitate and enhance the production process.
6	not equippped with glass protector	Without protection on the glass during the shipping process, there is a risk that the glass will be damaged. Hence, The company might consider the option adding foam or additional shielding around the glass materials to ensure safe shipping
7	Inadequate air circulation	Companies can consider adding ventilation in certain areas to improve air circulation and air quality in the room. By installing adequate ventilation, there will be better air flow, reducing humidity levels , eliminating unpleasant odors, and reducing indoor pollution levels
8	Weather factors	While controlling the weather can be challenging, the company can consider to add ventilation and cooling systems such as fans
9	no routine machine maintenance	The company can condider implementing regular scheduled maintenance as a proactive approach to sustain the equipment or systems in prime condition and performance. These maintenance tasks are scheduled based on the machine's operational hours, necessitating the creation of a routine schedule, such as every 100 working hours, 500 working hours, and so forth, to ensure consistency
10	Machine component in poor condition/not function properly	Regular maintenance and inspection can help to avoid machine damage.
11	The measuring tools fails to meet the specified requirements	The company can exchange their current measuring tools with ones that align better with their requirements and improved specifications. The objective behind this replacement is to enhance precision, dependability, and efficiency throughout the measurement process
12	the workers doesn't have a knowlodge about Standard Operation Procedur	Training not only helps in increasing workers' knowledge and abilities regarding operating tools or machines, but also introduces standard operational procedures.
13	routine and monotonous work makes worker unmotivated	The company has the flexibility to implement break times, in addition to the one between 12-13, at 10 o'clock and 15 o'clock, each lasting for 15 minutes, to provide mental and physical rest for the employees.
14	undiscipline worker	Supervision during working hours
15	noise from operating machines	The workers are provided with personal protective equipment such as earplugs or earmuffs
16	lighting below standard	The working conditions at the company involve an enclosed space that currently relies on artificial lighting. Improving ventilation can positively impact the lighting conditions by increasing the amount of natural light. Further investigation is required regarding the amount of lighting that needs to be added.

3.3 The Simulation

The simulation is conducted under the assumption that the company adopts the recommendations. Based on the discussion with the company, it is anticipated that the implementation of these recommendations will lead to an alteration in both occurrence and detection ratings. Simulations were performed on the six failure modes classified as High, and the resultant shifts in AP values are outlined in Table 4, providing a comparison between the values before and after implementation.

Table 4. Comparison of AP Before and After Implementation

No	Process	Failure Mode	Before Implementation					After Implementation				
			S	O	D	RPN	AP	S	O	D	RPN	AP
1	Glass Cutting	Shattered glass.	10	7	7	490	H	10	3	5	150	M
2	Glass Cutting	Broken glass	9	7	7	441	H	9	2	5	90	M
3	Wood Cutting	the wood's size below standard	8	7	7	392	H	8	2	5	80	M
4	Glass Hole Punching	Cracks on glass	9	6	7	378	H	9	3	5	135	M
5	Wood Cutting	Broken wood	8	6	5	240	H	8	3	5	120	M
6	Glass Hole Punching	Shattered glass.	10	3	7	210	H	10	3	5	150	M

Note: S = Severity, O = Occurrence, D = Detection, RPN = Risk Priority Number, AP = Action Priority

Table 4 shows a change in the AP value, from the High category to Medium. This shows that the recommendations have the potential to improve the company's product quality.

4 Conclusion

The outcomes of this study reveal six critical areas for improvement, namely shattered glass on glass cutting process, Broken glass on glass cutting process, the wood's size below standard in wood cutting process, crack on glass hole punching process, broken wood on the wood cutting process and shattered glass on the glass hole punching process. Based on the root cause of problem identification by FTA, there are 16 root causes and the recommendations involve training, workload distribution, scheduling system, using updated equipment, adding more ventilation system, regular maintenance for machines and tools, using tools as requirements, implementing new break time system, supervision, and personal protective equipment. Based on simulations, the implementation of the recommendations is projected to result in a reduction of the AP category from High to Medium. Further studies are required to address workload distribution and workforce evaluation as well as to determine the appropriate amount of additional lighting needed.

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