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Proposed Improvements to Occupational Health and Safety (OHS) Using FMEA and FTA at Ruang Klambi Garment Workshop

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Abstract – **The garment industry is a crucial sector in the production of clothing and textiles, which supports societal needs. However, its production processes, involving various types of machinery and work tools, pose significant health and safety risks to employees. These risks need to be well managed to ensure workplace safety and to prevent potential accidents that could harm both employees and the company. This study was conducted at Ruang Klambi, a small garment industry located in South Tangerang. The purpose of the study is to identify and analyze potential workplace accidents and provide recommendations for improvements to enhance occupational health and safety (OHS). In this research, two main methods were used for hazard identification: Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA). Through FMEA, 44 potential accidents were identified across 9 work activities in the clothing and textile production process. Subsequently, FTA was used to identify the root causes of these potential accidents. The analysis revealed 42 root causes, which were then simplified to 34 main root causes after the cutset process. Based on these root causes, recommendations were developed focusing on the prevention and control of potential workplace accidents. The implementation of these improvement recommendations is expected to significantly enhance the level of OHS at Ruang Klambi, creating a safer and more productive work environment for all employees.**

Keywords – *failure modes and effects analysis, fault tree analysis, occupational health and safety*

INTRODUCTION

The garment manufacturing industry plays a vital role in producing clothing and textiles. In the production process, various machines are used for different activities, which pose potential risks to workers' health and safety. Therefore, occupational health and safety (OHS) concerns in this industry must be taken seriously. Employees in this sector are frequently exposed to hazardous conditions. To address this issue, we conducted a study at a small-scale garment manufacturer named Ruang Klambi, located in South Tangerang. This research employed two hazard identification methods: Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA). The aim is to identify areas that require improvement and provide recommendations to enhance occupational health and safety at Ruang Klambi.

Failure Mode Effect Analysis (FMEA)

FMEA is a methodology used to evaluate potential failures in a system, design, process, or service [1]. It has been widely applied to address issues related to prioritizing corrective actions. In traditional FMEA, failure modes are scored by calculating the Risk Priority Number (RPN), which is the product of three factors: occurrence, severity, and detection [2]. The main objective of FMEA is to assess the level of risk associated with each type of failure to determine whether preventive actions are needed. FMEA is also useful for minimizing losses resulting from process failures or product malfunctions experienced by end users [3]. It is

typically applied when introducing a new process, implementing preventive measures before problems occur, identifying detection tools for potential failures, making equipment modifications or replacements, and relocating components or processes. The advantages of FMEA include cost-efficiency, since it systematically focuses on potential causes of failure, and time-efficiency, due to its relevance to ongoing production processes [4].

Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is an analytical technique used to break down cause-effect relationships of an event into a fault tree model. This method focuses on identifying failures or damages with the highest level of criticality, referred to as the undesired top-level event. The analysis begins by defining this undesired event, then systematically explores all possible incidents and errors that may contribute to the failure, along with their underlying causes [5]. FTA utilizes this approach to examine cause-effect relationships within a system. Simply put, it is a graphical model that maps out the logical interrelationships between various basic failures or events that could lead to the top event defined earlier [6]. A cut set in FTA is a combination of basic events that, if they occur simultaneously, would cause the undesired top-level event. Identifying cut sets is valuable for understanding combinations of failures that could lead to system breakdowns, and therefore supports risk reduction efforts [7].

METHOD

This research aims to analyze occupational health and safety (OHS) risks at Ruang Klambi using a structured and systematic approach. The methodology begins with identifying and formulating the research problem, followed by setting objectives and conducting a literature review to support the analysis framework. Two hazard analysis methods are employed in this study: Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA). Primary data is collected through direct interviews at the company site. The FMEA method is used to identify failure modes, calculate their Risk Priority Numbers (RPN), and prioritize the risks. The results are then further analyzed using FTA to determine the root causes of potential workplace accidents. Finally, the research provides recommendations for improving the existing occupational health and safety system.

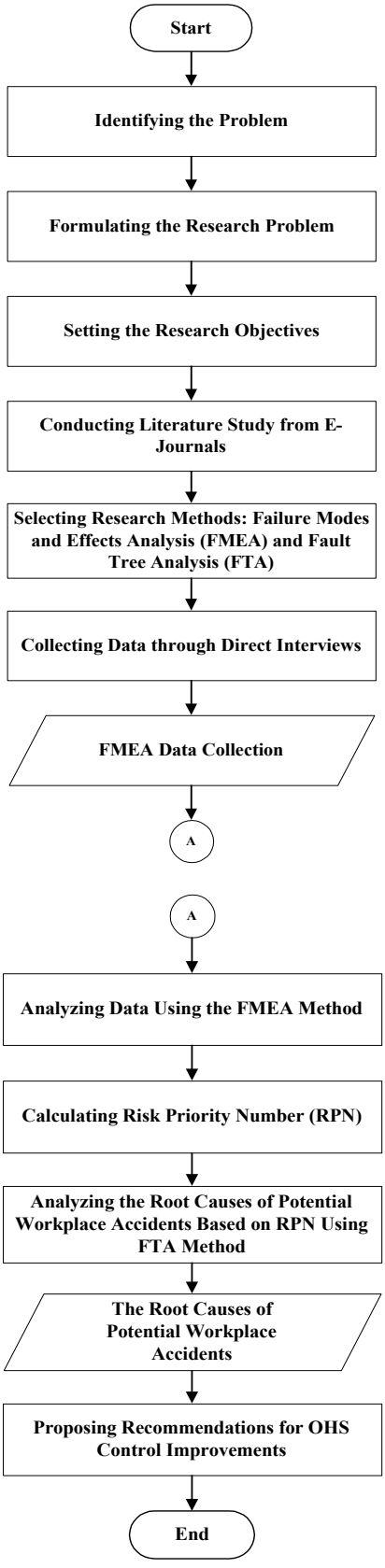

Figure 1. Research Flowchart

RESULTS AND DISCUSSION

Data Collection

In this study, data were collected through direct interviews with four employees at Ruang Klambi, a small-scale garment industry. The data collected follow the FMEA method and include potential workplace accidents along with their effects, causes, and the current control measures in place.

Figure 2. Pattern Making and Cutting

Figure 2 shows the pattern making and cutting process, performed by Employee 1.

Figure 3. Fabric Cutting

Figure 3 shows the fabric cutting process, performed by by Employee 1.

Figure 4. Overlock Stitching

Figure 4 shows the overlock stitching process, performed by Employee 2.

Figure 5. Garment Sewing

Figure 5 shows the garment sewing process, performed by Employee 3.

Figure 6. Buttonhole Making

Figure 6 shows the buttonhole making process, performed by Employee 4.

Figure 7. Button Attaching

Figure 7 shows the process of attaching buttons, performed by Employee 4.

Figure 8. Ironing

Figure 8 shows the garment ironing process, performed by Employee 4.

Figure 9. Garment Packaging

Figure 9 shows the garment packaging process, performed by Employee 4.

***Failure Mode Effect Analysis* (FMEA)**

The results of data collection using the FMEA method are presented in Table 1.

Table 1. Failure Mode Effect Analysis (FMEA) Data

No	Activity	Failure Mode
1	Pattern Making	- Eye strain - Wrist injury - Back pain
2	Pattern Cutting	- Cut by scissors
3	Fabric Cutting	- Cut by fabric cutter machine - Eye strain - Back pain
4	Overlock Stitching	- Cut by thread scissors
5	Fabric Sewing	- Pierced by needle - Cut by thread scissors - Eye strainBack pain
6	Buttonhole Making	- Pinched by machine parts - Pierced by needle - Cut by thread scissors - Eye strain - Back pain
7	Button Attaching	- Pierced by needle - Cut by thread scissors - Eye strain - Back pain
8	Garment Ironing	- Burned by hot iron - Back pain
9	Garment Packaging	- Tripped over plastic - Back pain

Table 1 shows the identified potential workplace accidents across 9 activities in the garment production process at Ruang Klambi. Each activity may involve more than one potential cause of workplace accidents.

Data Processing

After the data collection, the next step is to calculate the Risk Priority Number (RPN) in the FMEA table to identify and prioritize existing risks. This stage aims to determine which areas require immediate corrective actions to improve occupational health and safety at Ruang Klambi. By calculating the RPN, better-informed decisions can be made in managing risks and implementing effective preventive measures.

Table 2. Risk Priority Number (RPN) Score

No	Activity	Failure Mode	Effect of Failure Mode	S	Cause of Failure Mode	O	Current Control	D	RPN
1	Pattern Making	Eye fatigue	Temporary blurry vision	2	Poor lighting	1	Install bright lights in the work area	2	4
				2	Intense focus for too long	8	Provide break time for workers	3	48
		Wrist injury	Hand cramps	2	Prolonged use of pencil	6	None	10	120
		Back injury	Back pain	3	Bent-over working posture for too long	3	None	10	90
2	Pattern Cutting	Cut by scissors	Hand injury	3	Lack of focus	6	Advise workers to stay focused and careful	2	36
3	Fabric Cutting	Cut by fabric cutter machine	Hand injury	3	Lack of focus	8	Advise workers to stay focused and careful	4	96
				3	Fabric too thick	2	Limit the number of fabrics cut at once	2	12
				3	Dull blade	2	Replace the blade if dull	2	12
		Eye fatigue	Temporary blurry vision	2	Poor lighting	1	Install bright lights in the work area	3	6
				2	Intense focus for too long	7	Provide break time for workers	3	42

No	Activity	Failure Mode	Effect of Failure Mode	S	Cause of Failure Mode	O	Current Control	D	RPN
		Back injury	Back pain	3	Bent-over working posture for too long	7	None	10	210
4	Overlock Sewing	Cut by thread scissors	Hand injury	3	Lack of focus	8	Advise workers to stay focused and careful	4	96
				3	Dull scissors	2	Sharpen scissors if dull	2	12
5	Fabric Sewing	Pierced by needle	Hand injury	3	Lack of focus	8	Advise workers to stay focused and careful	4	96
				3	Untrained	6	None	10	180
				3	Sewing machine jam	3	Repair the sewing machine if jammed	2	18
				3	Poor lighting	1	Install additional lighting on sewing machine	3	9
		Cut by thread scissors	Hand injury	3	Lack of focus	8	Advise workers to stay focused and careful	4	96
				3	Dull scissors	2	Sharpen scissors if dull	2	12
		Eye fatigue	Temporary blurry vision	2	Poor lighting	1	Install additional lighting on sewing machine	3	6
				2	Intense focus for too long	9	Provide break time for workers	4	72

No	Activity	Failure Mode	Effect of Failure Mode	S	Cause of Failure Mode	O	Current Control	D	RPN
		Back injury	Back pain	3	Bent-over working posture for too long	9	None	10	270
6	Buttonhole Making	Pinched by machine parts	Slight hand pain	2	Carelessness	3	Advise workers to be careful	3	18
		Pierced by needle	Hand injury	3	Lack of focus	7	Advise workers to stay focused and careful	3	63
				3	Buttonhole machine jam	2	Repair the buttonhole machine if jammed	2	12
				3	Poor lighting	1	Install additional lighting on buttonhole machine	2	6
		Cut by thread scissors	Hand injury	3	Lack of focus	7	Advise workers to stay focused and careful	3	63
				3	Dull scissors	2	Sharpen scissors if dull	2	12
		Eye fatigue	Temporary blurry vision	2	Poor lighting	1	Install additional lighting on buttonhole machine	2	4
				2	Intense focus for too long	9	Provide break time for workers	2	36

No	Activity	Failure Mode	Effect of Failure Mode	S	Cause of Failure Mode	O	Current Control	D	RPN
		Back injury	Back pain	3	Bent-over working posture for too long	9	None	10	270
7	Button Attaching	Pierced by needle	Hand injury	3	Lack of focus	7	Advise workers to stay focused and careful	3	63
				3	Button attaching machine jam	2	Repair the button attaching machine if jammed	2	12
				3	Poor lighting	1	Install additional lighting on button attaching machine	2	6
		Cut by thread scissors	Hand injury	3	Lack of focus	7	Advise workers to stay focused and careful	3	63
				3	Dull scissors	2	Sharpen scissors if dull	2	12
		Eye fatigue	Temporary blurry vision	2	Poor lighting	1	Install additional lighting on button attaching machine	2	4
				2	Intense focus for too long	9	Provide break time for workers	2	36
		Back injury	Back pain	3	Bent-over working posture for too long	9	None	10	270
8	Garment Ironing	Burn from hot iron	Burn injury	4	Lack of concentration	6	Advise workers to stay focused and careful	3	72
				4	Crowded work table	3	Always tidy up work table	2	24

No	Activity	Failure Mode	Effect of Failure Mode	S	Cause of Failure Mode	O	Current Control	D	RPN
		Back injury	Back pain	3	Bent-over working posture for too long	3	None	10	90
9	Garment Packaging	Tripped over plastic	Bruise or minor injury	3	Scattered plastic	1	Tidy up plastics on the work table	2	6
		Back injury	Back pain	3	Bent-over working posture for too long	2	None	10	60

Table 2 presents the results of data processing, showing the RPN values. Based on the table, the highest RPN value was found in the potential risk of back injury, which occurred in three different activities: **fabric sewing**, **buttonhole making**, and **button attaching**, each with an RPN of **270**. Additionally, back injury was also identified during the **fabric cutting** activity with an RPN of **210**.

Another notable risk was needle puncture, which may occur during **fabric sewing**, with an RPN of **180**. Lastly, wrist injury during **pattern making** was also identified as a significant risk, with an RPN of **120**.

Fault Tree Analysis **(FTA)**

Following the FMEA analysis, the next step is to apply the Fault Tree Analysis (FTA) method by selecting the failure modes with the highest RPN values obtained from the FMEA. This step aims to identify and analyze the root causes of potential failures based on the prioritized risks. The results of this analysis will support the development of recommendations for workplace accident prevention and future safety improvements.

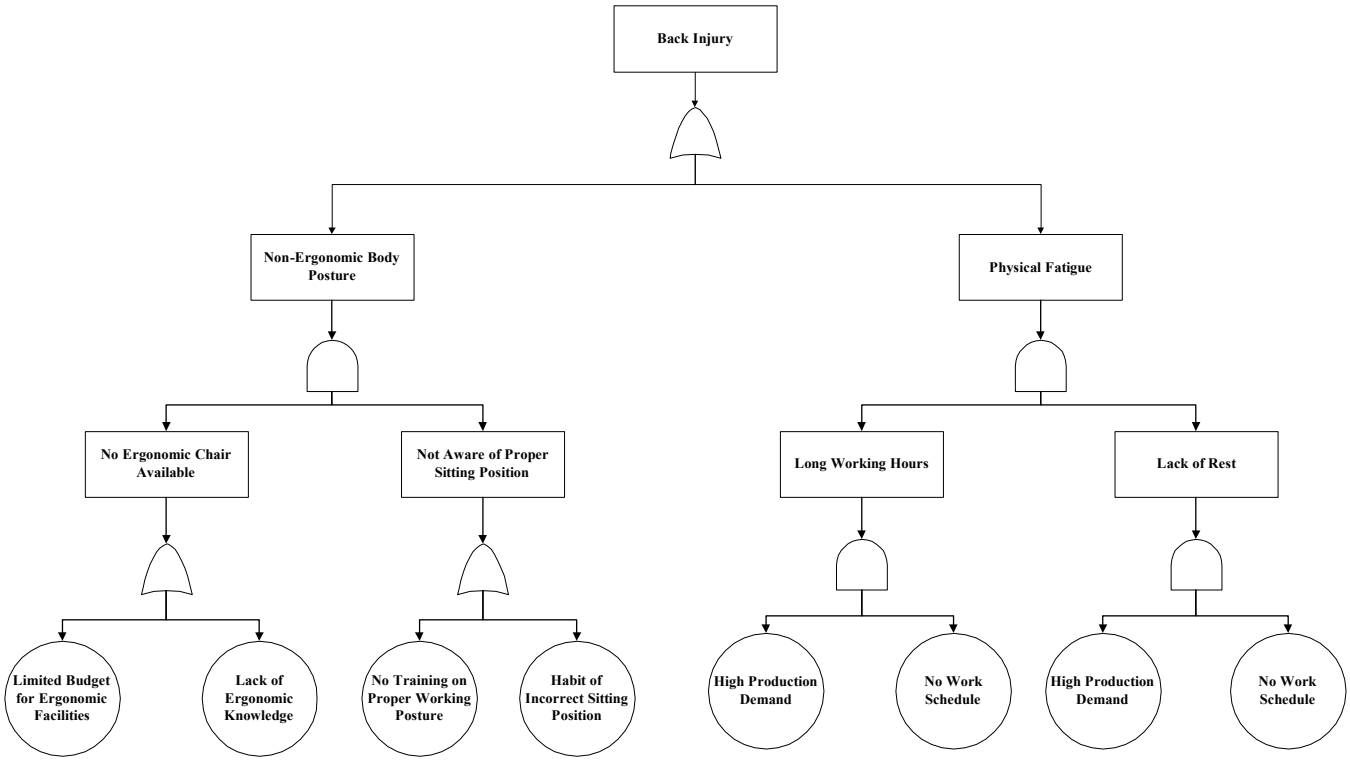

Figure 10. FTA Analysis of Back Injury in Fabric Sewing Activity

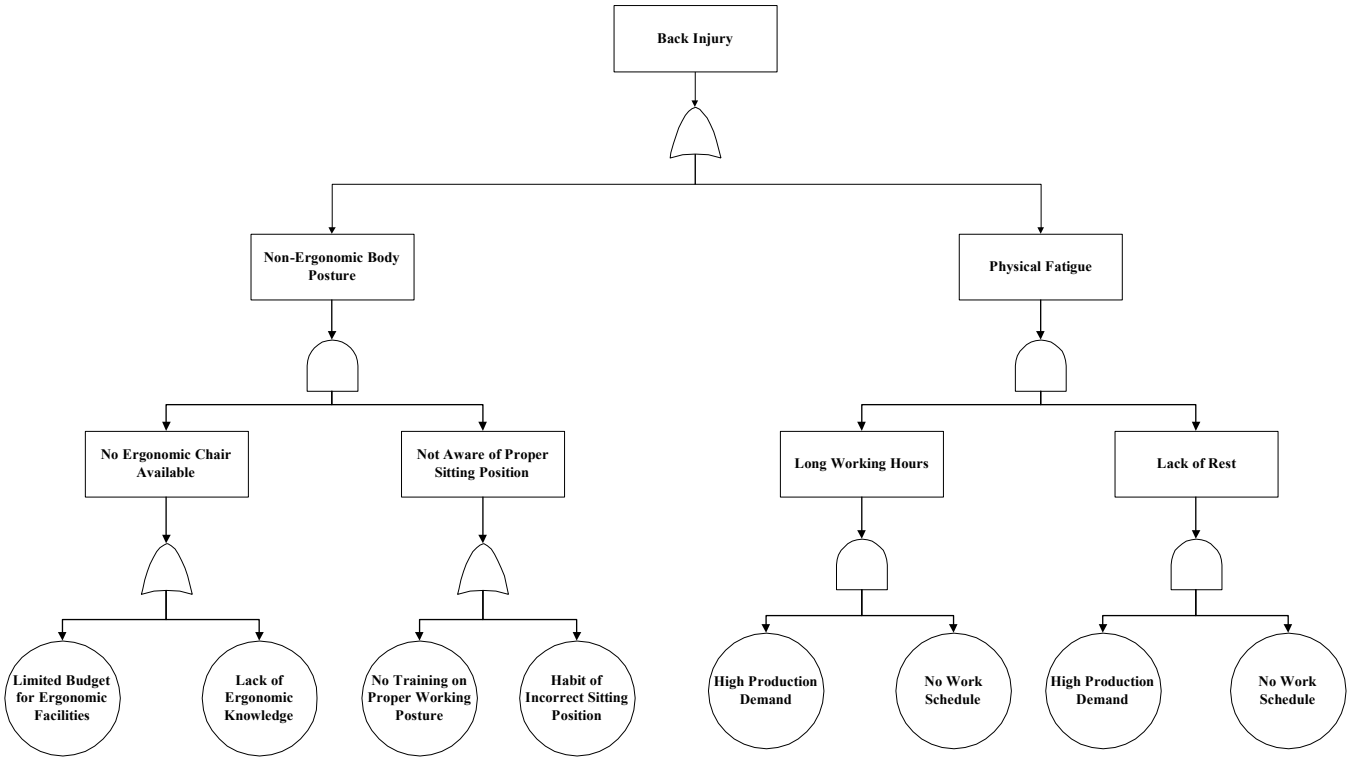

Figure 11. FTA Analysis of Back Injury in Buttonhole Making Activity

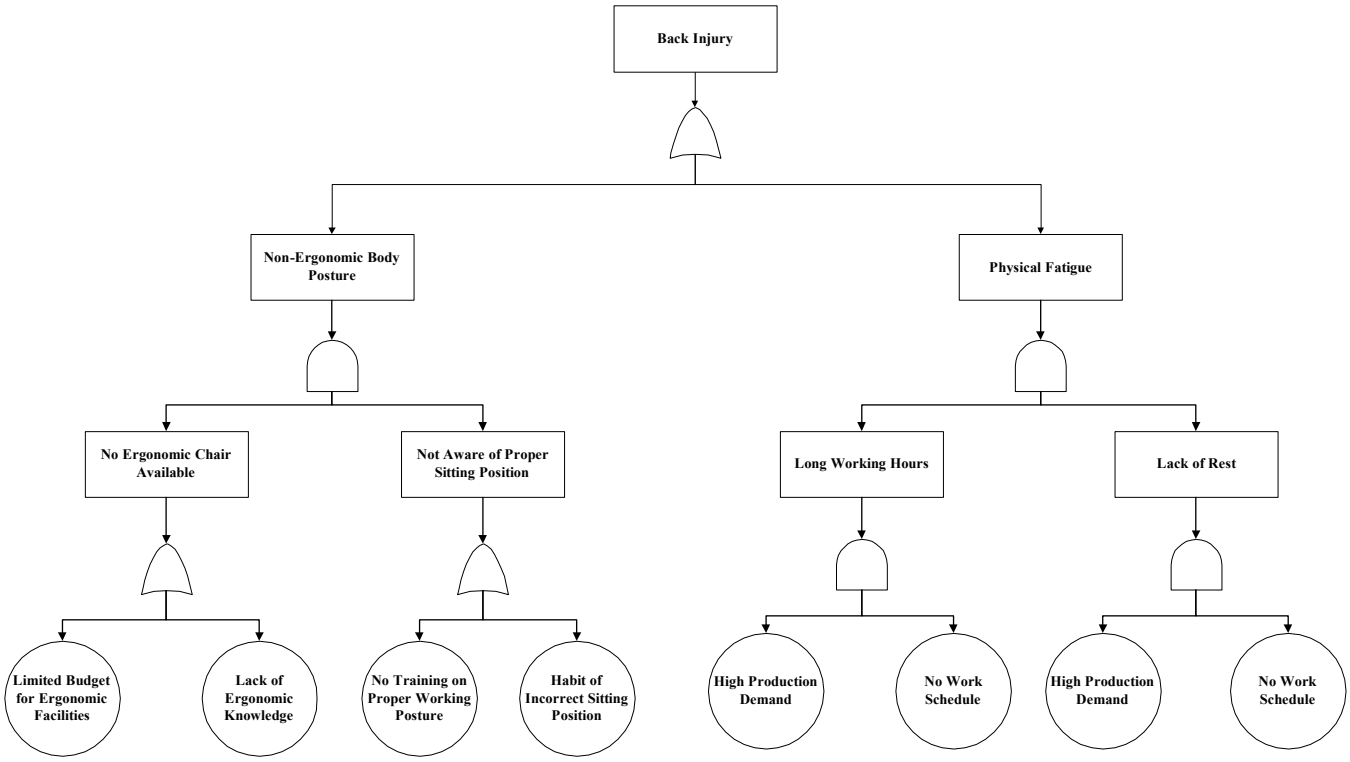

Figure 12. FTA Analysis of Back Injury in Button Attaching Activity

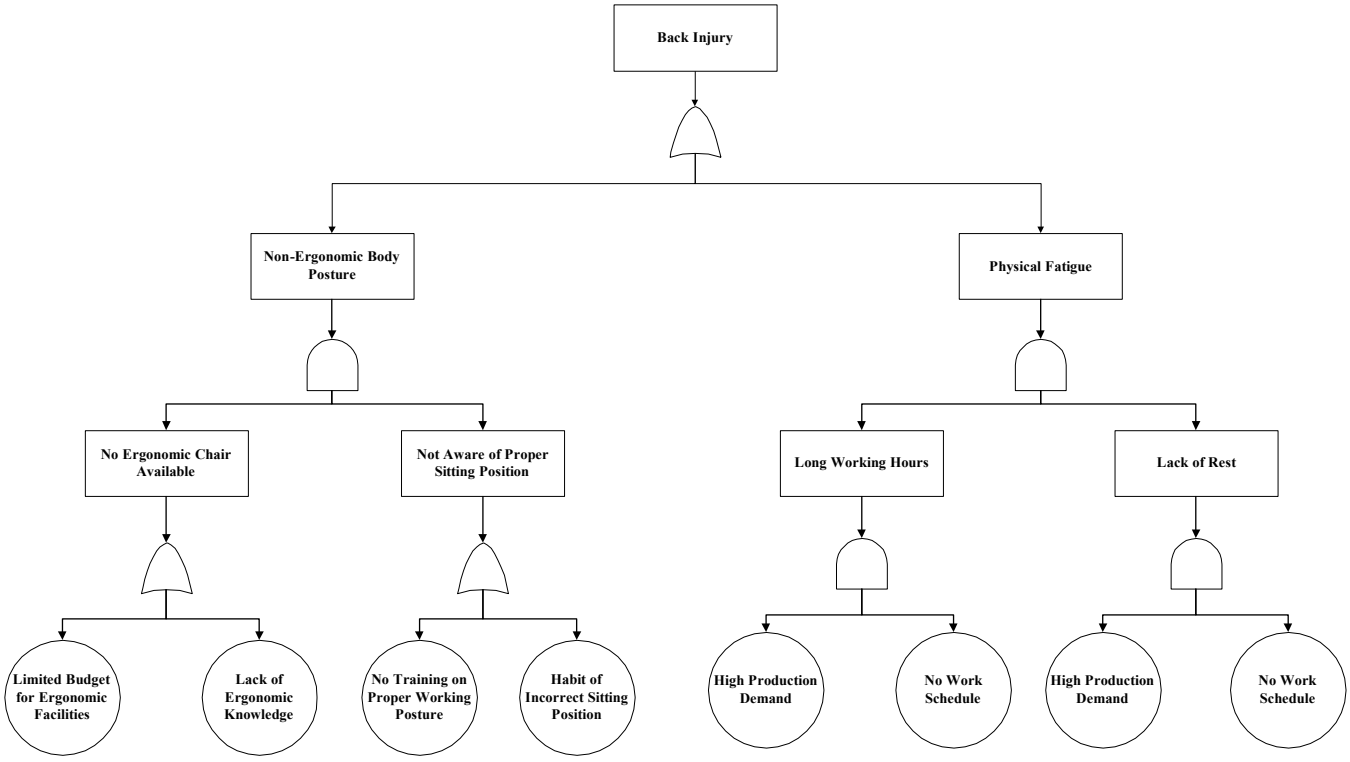

Figure 13. FTA Analysis of Back Injury in Fabric Cutting Activity

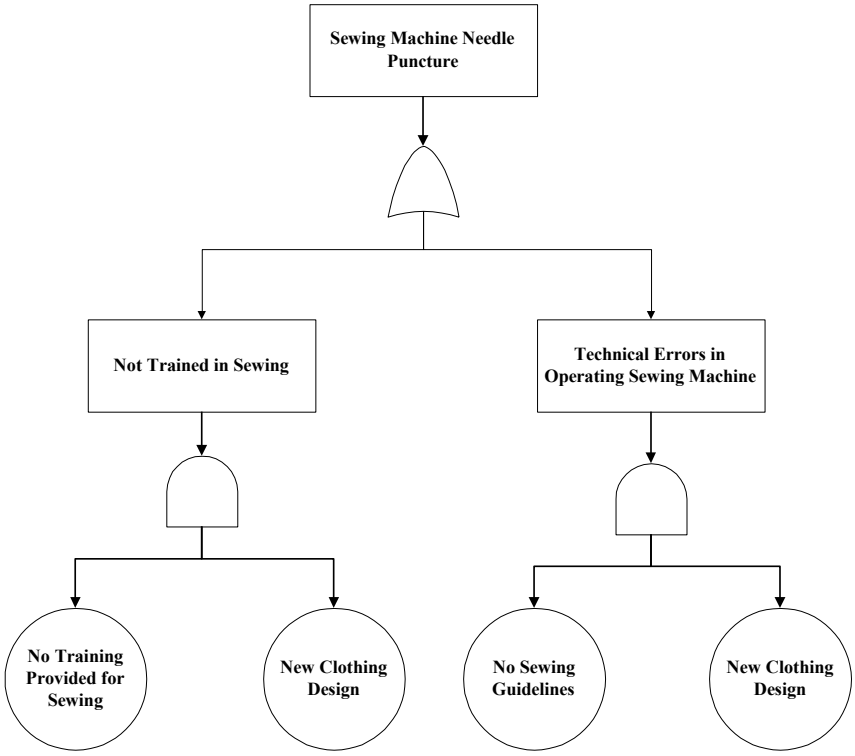

Figure 14. FTA Analysis of Needle Puncture in Fabric Sewing Activity

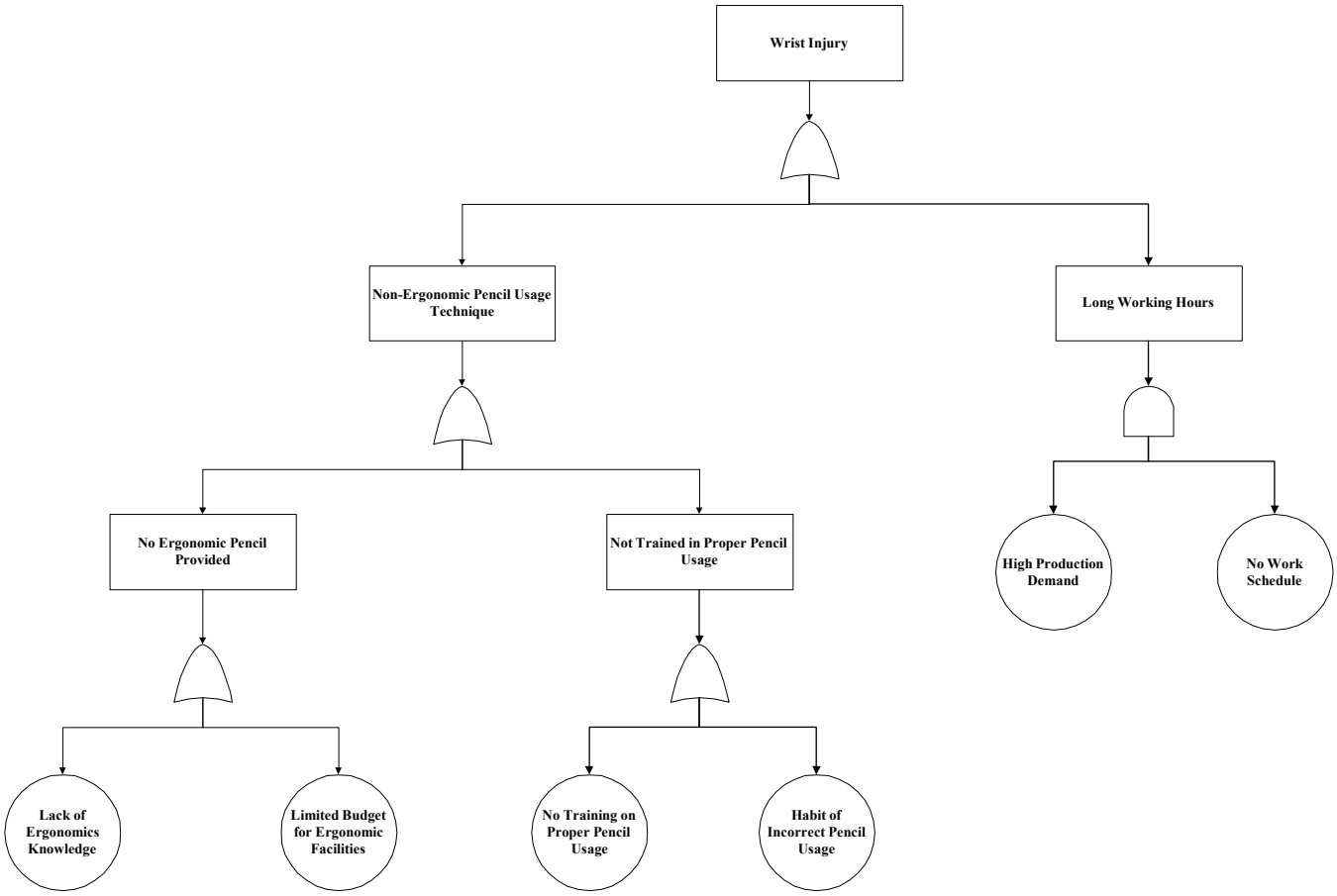

Figure 15. FTA Analysis of Wrist Injury in Pattern Making Activity

Based on the FTA analysis in Figures 10, 11, 12, 13, 14, and 15, there are 42 root causes of potential workplace accidents that require prioritized control improvements at Ruang Klambi.

Determining the Minimal Cutset

The next step is to determine the minimal cutset from each FTA analysis. The objective is to identify the simplest and most efficient combination of basic events that may lead to the occurrence of the top event.

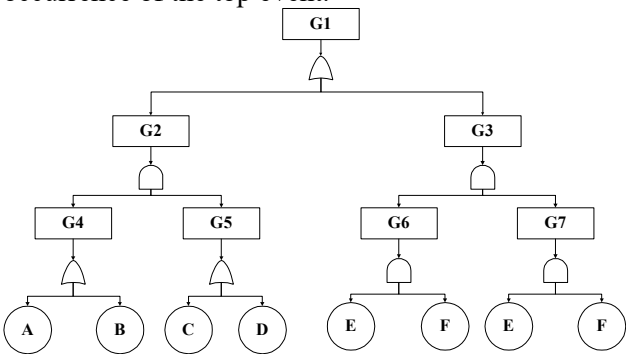

Figure 16. FTA Cutset Analysis of Back Injury in Fabric Sewing Activity

The cutset analysis was conducted using a top-down approach as follows:

G7 = E · F
G6 = E · F
G5 = C + D
G4 = A + B
G3 = G6 · G7
G2 = G4 · G5
G1 = G2 + G3

Substitute all values into G1.

G1 = G2 + G3
= (G4 · G5) + (G6 · G7)
= ((A + B) · (C + D)) + ((E · F) · (E · F))
= AC + AD + BC + BD + EF · EF
= AC + BD + EF

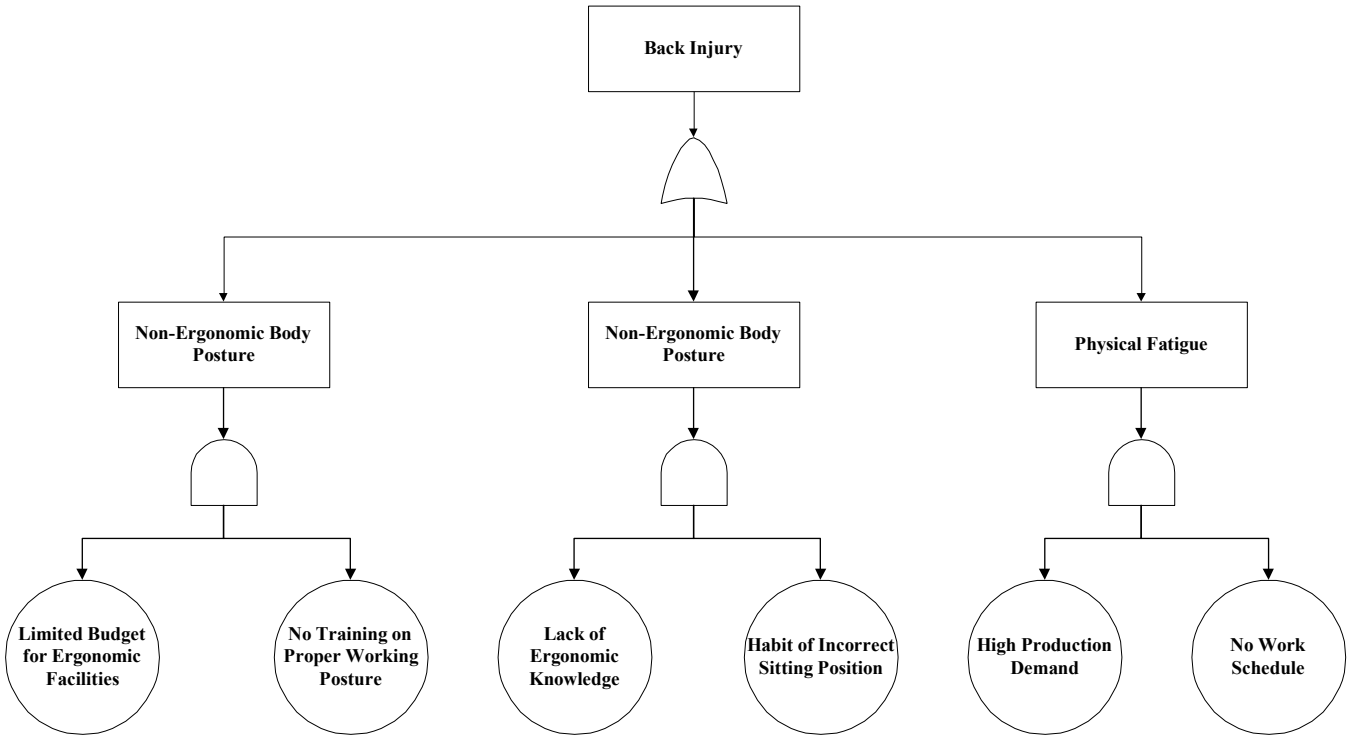

Figure 17. FTA Cutset of Back Injury in Fabric Sewing Activity

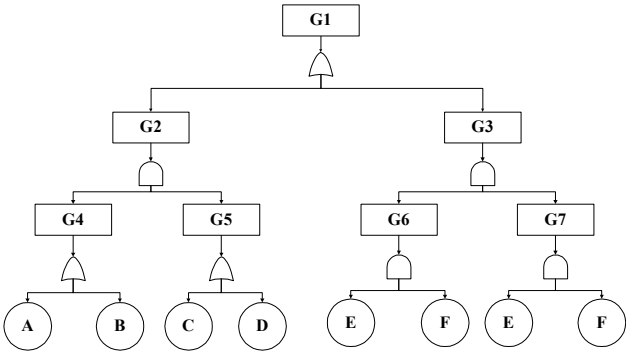

Figure 18. FTA Cutset Analysis of Back Injury in Buttonhole Making Activity

The cutset analysis was conducted using a top-down approach as follows:

G7 = E · F
G6 = E · F
G5 = C + D
G4 = A + B
G3 = G6 · G7
G2 = G4 · G5
G1 = G2 + G3

Substitute all values into G1.

G1 = G2 + G3
= (G4 · G5) + (G6 · G7)
= ((A + B) · (C + D)) + ((E · F) · (E · F))
= AC + AD + BC + BD + EF · EF
= AC + BD + EF

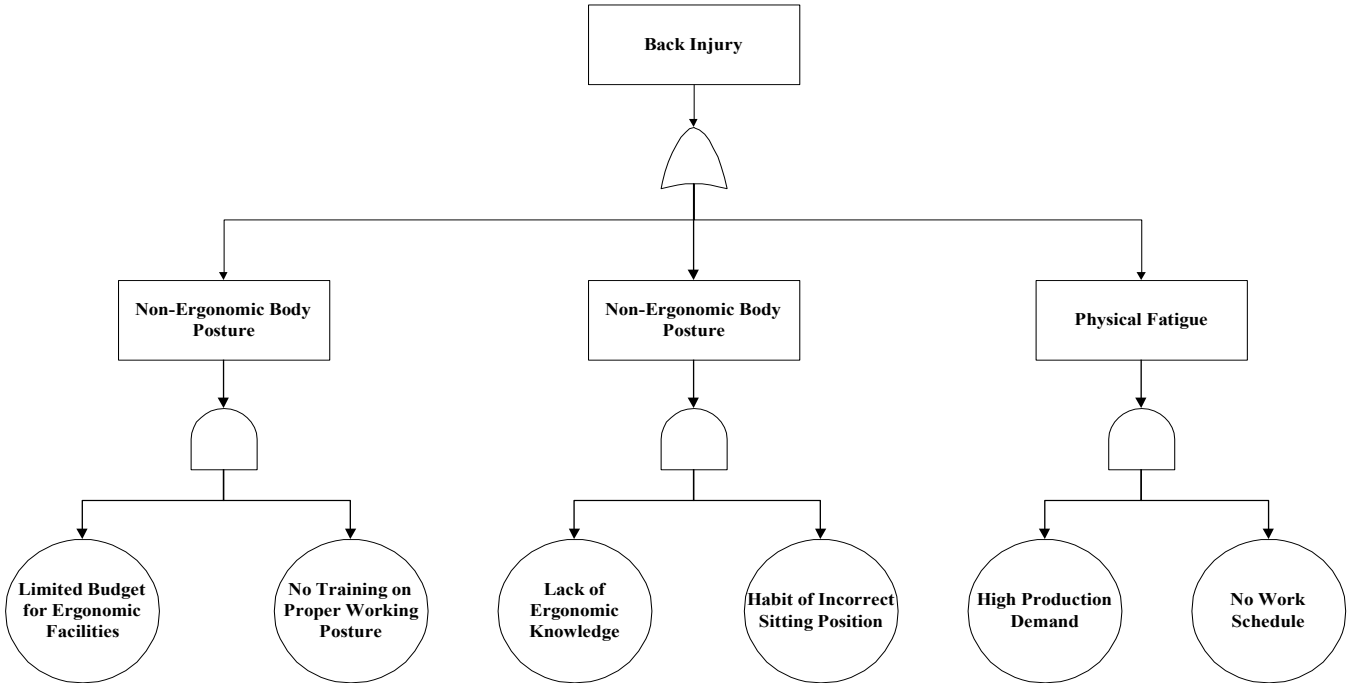

Figure 19. FTA Cutset of Back Injury in Buttonhole Making Activity

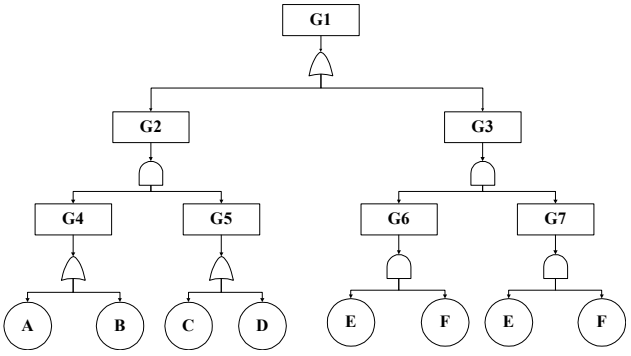

Figure 20. FTA Cutset Analysis of Back Injury in Button Attaching Activity

The cutset analysis was conducted using a top-down approach as follows:

G7 = E · F
G6 = E · F
G5 = C + D
G4 = A + B
G3 = G6 · G7
G2 = G4 · G5
G1 = G2 + G3

Substitute all values into G1.

G1 = G2 + G3
= (G4 · G5) + (G6 · G7)
= ((A + B) · (C + D)) + ((E · F) · (E · F))
= AC + AD + BC + BD + EF · EF
= AC + BD + EF

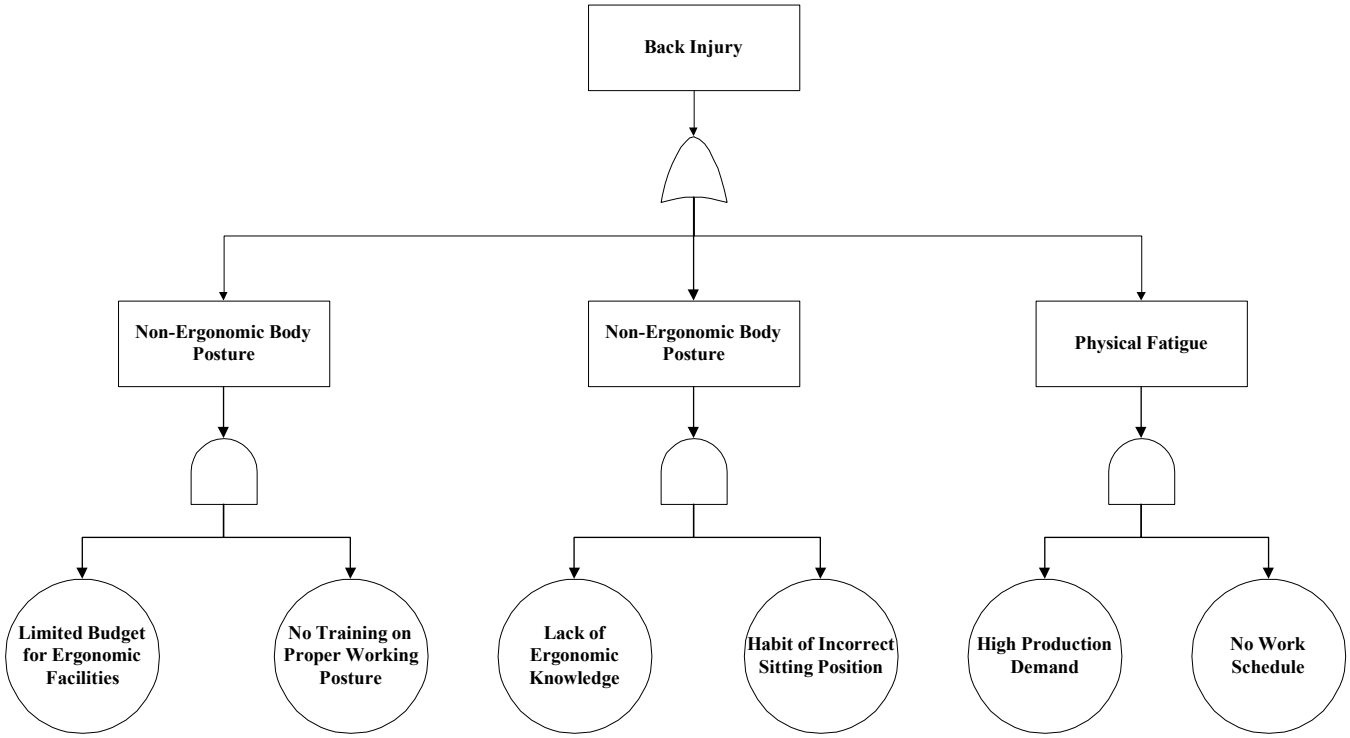

Figure 21. FTA Cutset of Back Injury in Button Attaching Activity

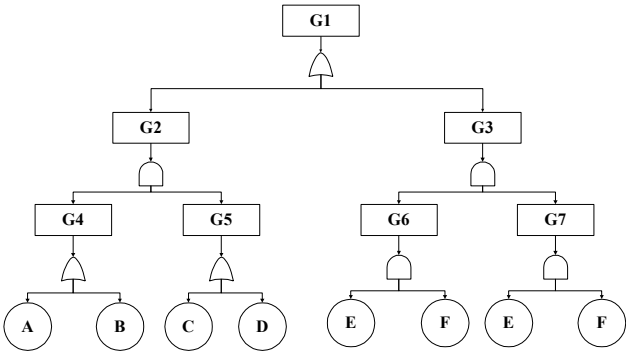

Figure 22. FTA Cutset Analysis of Back Injury in Fabric Cutting Activity

The cutset analysis was conducted using a top-down approach as follows:

G7 = E · F
G6 = E · F
G5 = C + D
G4 = A + B
G3 = G6 · G7
G2 = G4 · G5
G1 = G2 + G3

Substitute all values into G1.

G1 = G2 + G3
= (G4 · G5) + (G6 · G7)
= ((A + B) · (C + D)) + ((E · F) · (E · F))
= AC + AD + BC + BD + EF · EF
= AC + BD + EF

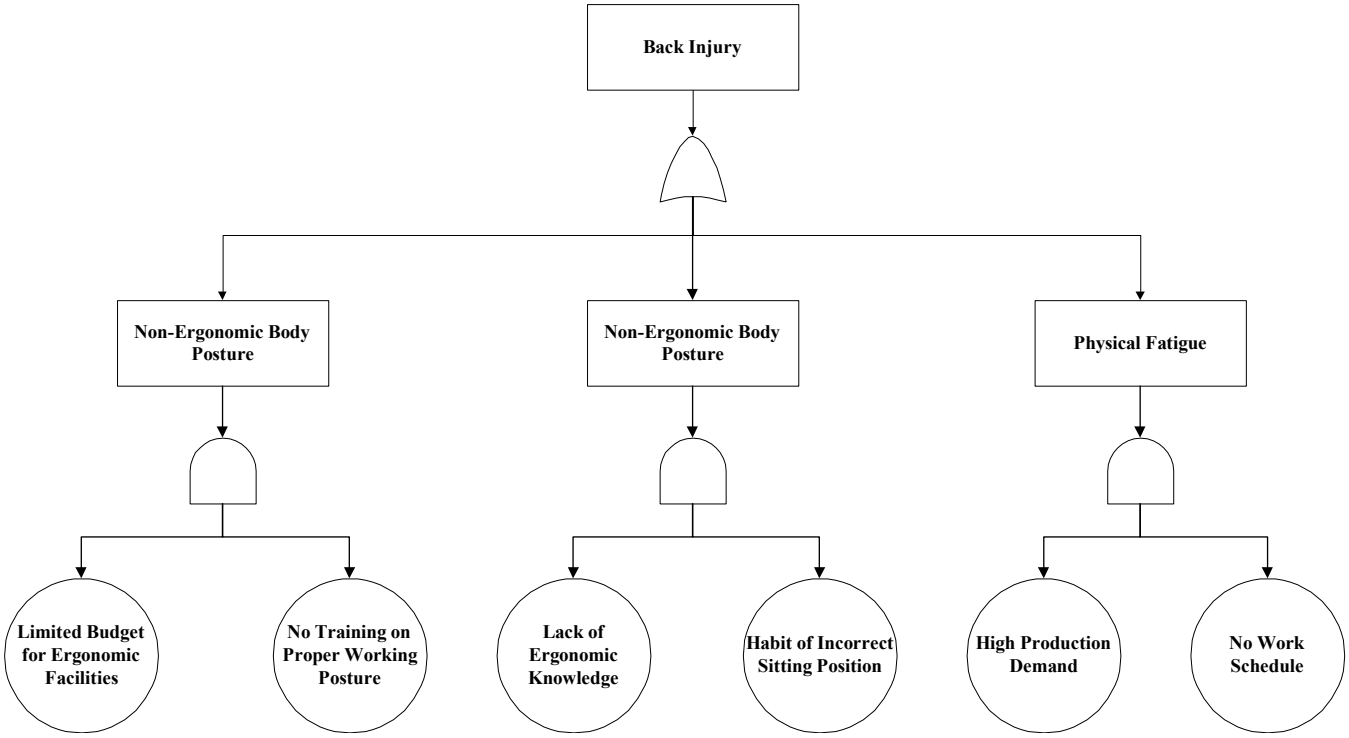

Figure 23. FTA Cutset of Back Injury in Fabric Cutting Activity

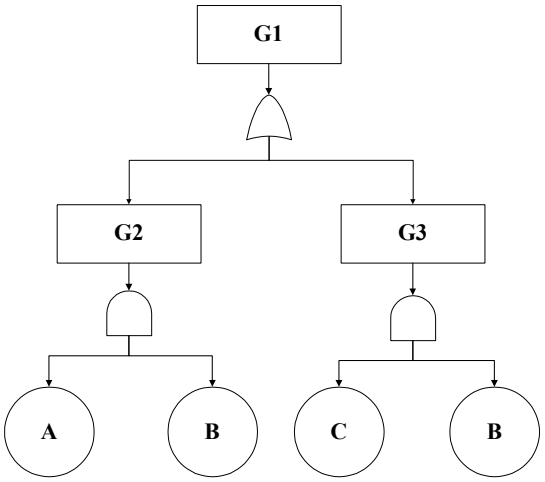

Figure 24. FTA Cutset Analysis of Needle Puncture in Fabric Sewing Activity

The cutset analysis was conducted using a top-down approach as follows:

G3 = C · B
G2 = A · B
G1 = G2 + G3

Substitute all values into G1.

G1 = G2 + G3
= (A · B) + (C · B)
= AB + CB

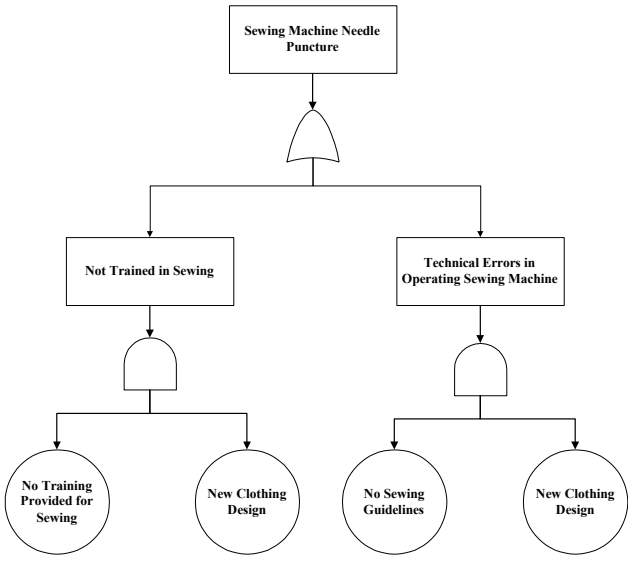

Figure 25. FTA Cutset of Needle Puncture in Fabric Sewing Activity

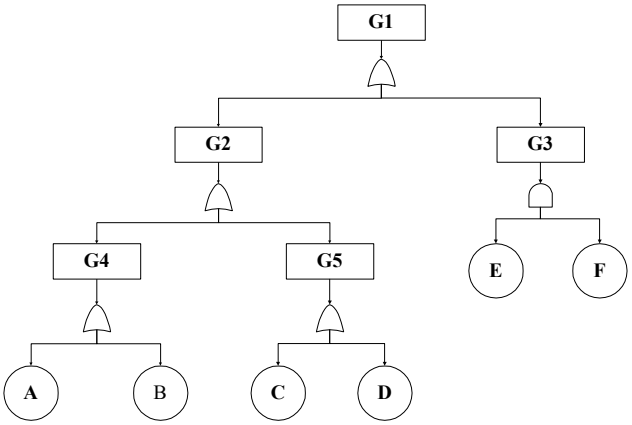

Figure 26. FTA Cutset Analysis of Wrist Injury in Pattern Making Activity

The cutset analysis was conducted using a top-down approach as follows:

G5 = C + D
G4 = A + B
G3 = E · F
G2 = G4 + G5
G1 = G2 + G3

Substitute all values into G1.

G1 = G2 + G3
= (G4 + G5) + (E · F)
= ((A + B) + (C + D)) + (E · F)
= A + B + C + D + EF

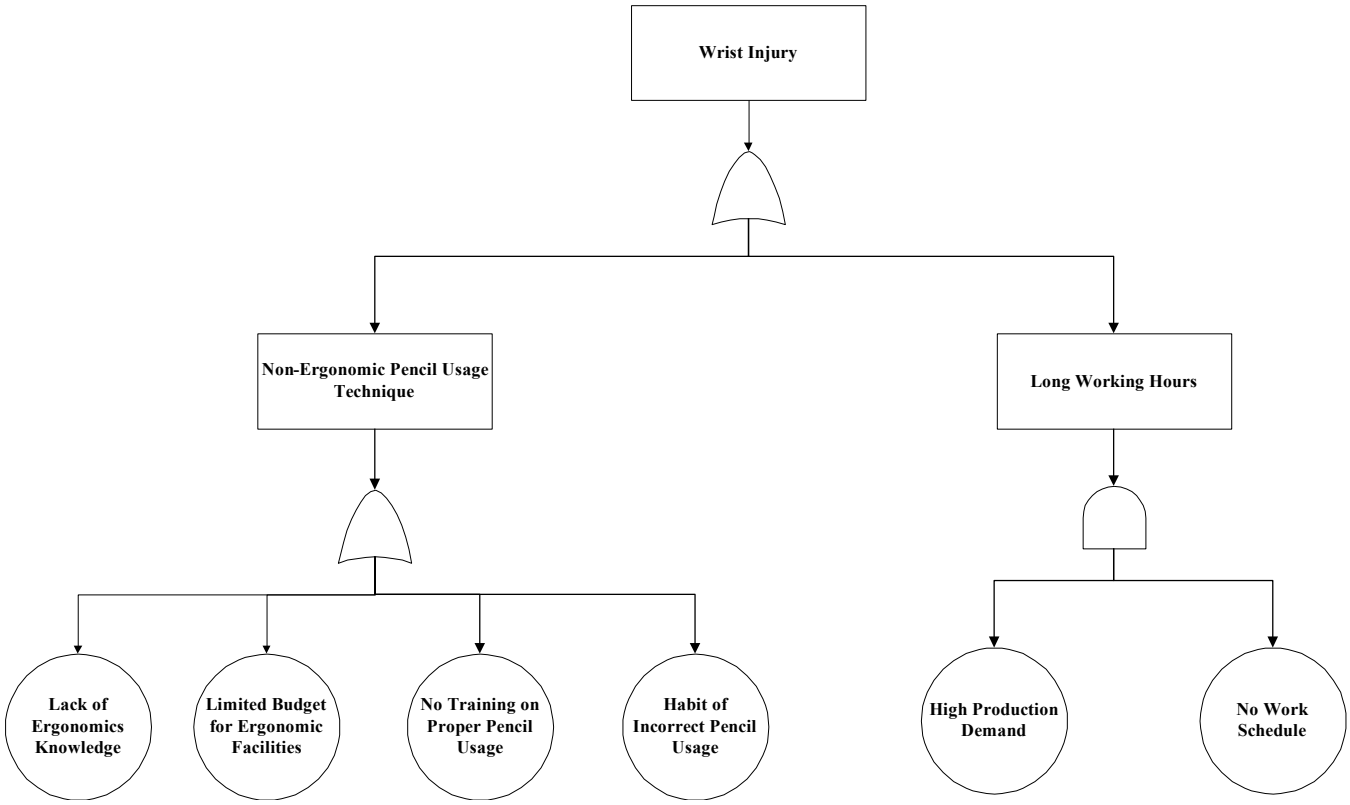

Figure 27. FTA Cutset of Wrist Injury in Pattern-Making Activity

Improvement Recommendations

Based on the results of the Fault Tree Analysis of potential workplace accidents at Ruang Klambi, we propose the following improvement recommendations to minimize the risk of accidents and enhance the quality of occupational health and safety at the workshop:

Table 3. Improvement Recommendations

No	Category of Root Cause	Recommended Improvements
1	Lack of Knowledge About Ergonomics	- Management conducts ergonomic work studies - Provide education and training on proper posture and ergonomic tool usage - Install posters with brief good practice guides
2	Limited Budget for Ergonomic Work Facilities	- Prioritize investment in ergonomic tools (e.g., ergonomic chairs, adjustable tables, scissors, pencils) - Gradually replace tools based on available capital
3	Employees Chasing High Production Demand Targets	- Adjust production targets to be more realistic - Create a structured work schedule
4	No Specialized Sewing Training	- Provide sewing training for new designs by assigning experienced workers as trainers
5	No Guidelines for Specific Sewing Techniques	- Develop Standard Operating Procedures (SOPs) for each process of sewing new designs

CONCLUSION

The conclusion drawn from this research on identifying potential workplace accidents at the Ruang Klambi garment workshop is as follows: Based on the identification using the FMEA method, 44 potential accidents were found across 9 work activities involved in garment and textile production. Furthermore, the FTA analysis identified 42 root causes that serve as the main priorities for accident prevention. After conducting the cutset process, 34 simplified root causes were obtained. Improvement suggestions were then proposed to prevent and control potential accidents as part of an effort to improve occupational health and safety (OHS) at Ruang Klambi, aiming to create a safe and productive work environment for all employees.

ACKNOWLEDGEMENTS

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