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Lecture Notes in Mechanical Engineering

Siti Nadiah Mohd Saffe
Siti Zubaidah Ismail
Cucuk Nur Rosyidi
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Proceedings of the 7th Asia Pacific Conference on Manufacturing Systems and 6th International Manufacturing Engineering Conference—Volume 1

iMEC-APCOMS 2024, Melaka, Malaysia

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Editors

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Preface

We are delighted to present the proceedings of the fourth edition of the 6th International Manufacturing Engineering Conference and the 7th Asia-Pacific Conference on Manufacturing System (iMEC-APCOMS 2024), hosted by Universiti Malaysia Pahang Al-Sultan Abdullah through its Faculty of Manufacturing and Mechatronic Engineering Technology. Held on September 11 and 12, 2024, the conference embraced the theme of "Sustainable Development Goals through Innovative Manufacturing Engineering."

iMEC-APCOMS 2024 has attracted a remarkable 99 submissions, all of which underwent a rigorous single-blind review process. Based on the recommendations of our dedicated reviewers, 44 papers were selected for publication in Volume 1 of the conference proceedings. We are immensely grateful to all contributing authors whose research has added great value to this collection. Each paper in this volume was thoughtfully evaluated by our esteemed technical review committee, comprised of leading experts in manufacturing engineering.

The conference served as a vibrant forum for the exchange of pioneering ideas and insights, highlighted by keynote presentations from distinguished speakers, including Prof. Ir. Dr. Nik Mohd Zuki Nik Mohamed (Universiti Malaysia Pahang Al-Sultan Abdullah, Malaysia), Prof. Dr. Cucuk Nur Rosyidi (Universitas Sebelas Maret, Indonesia), and Prof. Dr. Ir. Anas Ma'ruf (Institut Teknologi Bandung, Indonesia).

In closing, we hope that readers find this volume insightful and enriching. Our sincere appreciation goes to Springer Lecture Notes of Mechanical Engineering for their invaluable support in bringing this publication to life. Additionally, we extend our heartfelt thanks to the conference organizers and the dedicated members of the Conference Committee, whose tireless efforts made iMEC-APCOMS 2024 a resounding success.

Pekan, Malaysia — Siti Nadiah Mohd Saffe
Pekan, Malaysia — Siti Zubaidah Ismail
Surakarta, Indonesia — Cucuk Nur Rosyidi
London, UK — Mohammad Osman Tokhi

Contents

Improvement Production Performance Using Sustainable Lean Approach: A Case Study in Shoe Manufacturer

Tiena Gustina Amran, Emelia Sari, Aishah Zahra Setiawan, Ellyana Amran, Annisa Dewi Akbari, and Mohd Yazid Abu

Abstract Company X, an Indonesian shoe manufacturer, encountered significant challenges in meeting production targets and maintaining quality standards from July to December 2021, with defect rates surpassing 0.1%. This study aims to enhance shoe production by applying a sustainable lean production approach. By employing Process Activity Mapping and Sustainable Value Stream Mapping, the analysis identified four significant types of waste: defects, waiting, transportation, and excessive motion. The initial Process Cycle Efficiency of 42% is projected to improve to 53% following the proposed interventions. Additionally, the effort required to implement sustainable practices measured in the Sustainability Index was initially calculated at 125.88% and is expected to improve to 98.87% with the recommended improvements. Critical proposed solutions include Failure Mode and Effects Analysis, the introduction of machine checklist sheets, auxiliary tools, operator training, material handling modifications, process tool redesign, eliminating non-value-added activities, and implementation of the 6R framework. These solutions are designed to enhance efficiency, reduce waste, and support Company X's sustainability objectives.

Keywords Sustainable lean production · Sustainable value stream mapping · Process activity mapping · Sustainability index · Failure mode and effect analysis

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1 Introduction

A manufacturing company operates as an integrated business entity where people, machines, methods, money, materials, and the environment are part of a cohesive system. In the quest to become global industry leaders, companies focus on enhancing the efficiency and effectiveness of their resources. Manufacturing involves transforming raw materials into finished goods through value-added steps, increasing market value. Resource efficiency and effectiveness are critical to optimizing the manufacturing production process.

One critical approach to improving product efficiency and effectiveness is emphasizing the final product's quality. High product quality can drive a company's success, particularly in manufacturing. By conducting thorough quality analyses, companies aim to minimize defects that may arise during production. Reducing defects lowers waste and signifies a robust and well-managed production system.

Shoe manufacturing is divided into three main stages: cutting, stitching, and assembling. The most critical assembly process combines the shoe's upper and bottom parts. Errors during assembly can be particularly costly for the company, making this stage the most crucial in ensuring the overall success of the production process.

Table 1 compares the production targets for four products at Company X. This comparison highlights the rationale for selecting AFL products as the focus of this study. Among the four products, AFL is the most in demand by customers. The company employs a make-to-order strategy to determine production quantities, meaning the production targets are directly based on customer requests. The differences between monthly production targets, particularly from October to December, are illustrated in Fig. 1. These discrepancies suggest that the company faces challenges related to the efficiency and effectiveness of its production processes.

Based on preliminary observations from October and November, it was found that 3.5% of the production target still needed to be met in October and 2.8% in November.

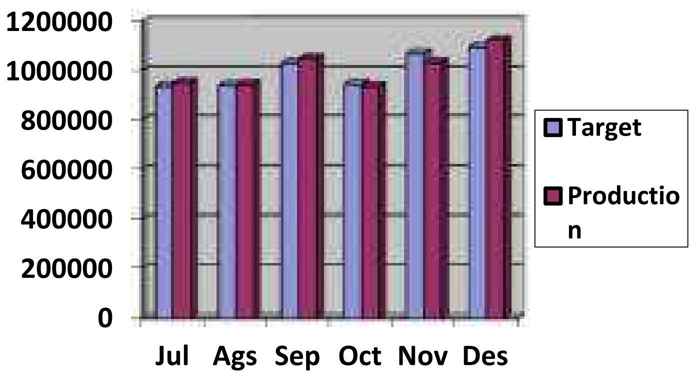


Fig. 1 Production target comparison for AFL products from October to December

Table 1 Product demand for October–December 2021

Product	Unit	Demand	Rank
AFL	Pairs	1,100,535	1
AMIL	Pairs	769,200	3
WF	Pairs	633,626	4
AM 95	Pairs	943,040	2

It was previously identified that the product suffered poor quality, leading to rejection. Many defects occurred in the assembly section, resulting in waste. According to quality control monitoring, product defects are classified into two grades: B-Grade, which has minor defects, and C-Grade, which has major (severe) defects. The acceptable defect rate for B-grade products is capped at 0.1% of the production volume, while C-grade products are limited to 0.01% of their production volume. Table 2 presents the monthly defect data for AFL products, categorized by defect type.

Figure 2 provides an overview of the shoe manufacturing process, highlighting the various types of waste generated. The outcome of this process can result in A-grade products, B-grade products, or unsellable items. A company aims to produce the highest quality products to minimize waste. Similarly, Company X strives to make its production process as efficient and effective as possible. However, when products are deemed unsellable, the company suffers financial losses. A mitigating analysis was conducted to identify the factors contributing to product defects.

Based on the explanation above, this research aims to design an improved production process using a sustainable lean production approach. The specific objectives are: (1) Identify and analyze the factors contributing to waste (2) Assess the implementation of the 6R principles in the production process (3) Propose improvements to minimize waste by applying Sustainable Value Stream Mapping (SVSM) and Process Activity Mapping (PAM) to enhance production efficiency (4) Measure the impact of Sustainable Lean Production (SLP) on the Sustainability Index (SI).

Table 2 The percentage of AFL product defects in July–December 2021

	Jul	Aug	Sep	Oct	Nov	Dec
Production	240,959	259,249	274,062	240,646	411,300	436,056
B-Grade (%)	0.02%	0.01%	0.12%	0.10%	0.13%	0.08%
C-Grade (%)	0.004%	0.003%	0.01%	0.001%	0.03%	0.002%

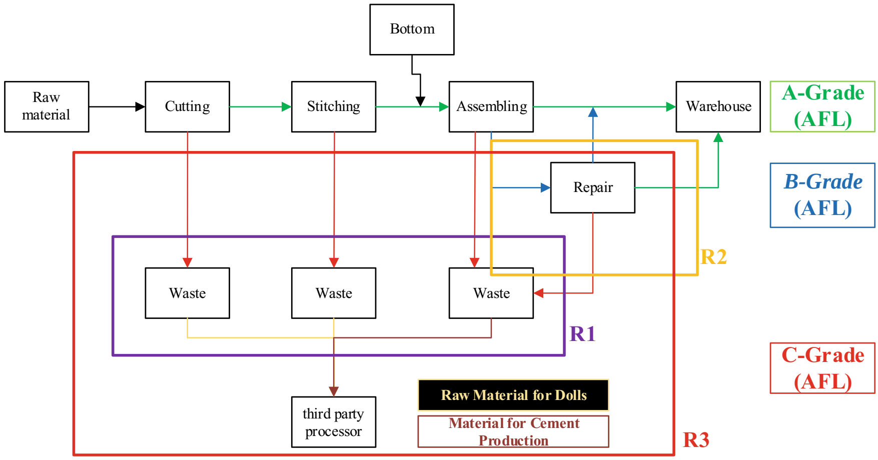


Fig. 2 Shoe manufacturing process

2 Literature Review

2.1 Lean Production

Lean production is characterized by systematic efforts to identify and eliminate waste or unproductive activities and to achieve continuous improvement in response to customer demands or in pursuit of perfection [1]. The lean approach seeks to maximize results while using minimal resources. At the core of lean principles is the emphasis on waste reduction [2]. Waste encompasses not only resource and financial inefficiencies but also includes any processes in production that are inefficient or ineffective [3].

Waste encompasses all work activities or processes that do not add value (non-value added) in the production process, from raw materials to the final product reaching the market. The eight fundamental types of waste in manufacturing systems include overproduction, excess inventory, defects, over-processing, waiting, unnecessary motion, underutilization of human resources, and inefficient transportation.

2.2 Sustainable Manufacturing, Sustainable Lean Production, and 6R Concept

Sustainable manufacturing minimizes negative impacts on the environment by minimizing natural resources, maintaining economic aspects, and maintaining the safety of workers, groups, and consumers [1]. Companies across various industries often face the challenge of waste generation. During the production process, the amount of waste produced can sometimes be substantial [4]. This waste includes materials that do not meet standards, items that are in-process but fall short of quality requirements, and finished products that fail to pass quality control. Sustainable lean production combines lean production principles with sustainable manufacturing, aiming to enhance the production process's environmental, economic, and social aspects [5].

The 3R concept is a concept that consists of three components. These components are reduced, reused, and recycled. Reuse is the use of waste that can still be used. Recycling is reprocessing discarded waste. The most important thing about the 3R concept is Reduce. Reduce minimizes wasted waste so there is no need to reuse or recycle [6]. From the 3R concept, it has grown to 6R. The other three components are recovery, redesign, and remanufacture.

2.3 Value Stream Mapping (VSM) and SVSM

VSM sketches the status of existing and future factory industrial layouts [1]. This tool requires tracing the activities that lead to the final product or service being delivered to the consumer and the activities performed step by step. VSM is a powerful tool for analyzing a company's production flow [7]. The use of VSM focuses on finding waste to optimize production [8]. It is a straightforward visual approach depicting the current material and information flows associated with a particular product family. VSM incorporates new ideas into the proposed picture of how materials and information should flow for the product group, resulting in an action plan that brings the new vision to life. Thus, lean tools and approaches will improve flow and efficiency while eliminating waste in manufacturing and industrial operations.

SVSM is the development of a value stream mapping tool used to identify and evaluate the production process by paying attention to sustainable aspects.

2.4 SI and Failure Mode and Effect Analysis (FMEA)

The SI calculates three aspects of sustainability: economic, environmental, and social. The resulting score quantifies the company's effort in terms of time and cost to advance sustainability [9]. Several categories were selected as indicators in this study, as presented in Tables 3 and 4.

Failure Mode and Effect Analysis (FMEA) is a testing tool used to identify, prioritize, and eliminate potential failures, focusing on prevention rather than reactive problem-solving [10]. Severity measures the impact of a failure, and its ranking can be reduced through design modifications. Occurrence indicates how frequently a cause of failure arises, with a ranking of 10 necessitating immediate action. Detection refers to the ability to identify a failure mode, and the Risk Priority Number (RPN) is calculated by multiplying severity, occurrence, and detection. A higher RPN indicates a greater need for corrective action [11].

3 Methods

Figure 3 shows the framework of thought used in this research. While Fig. 4 explains the flowchart of research methodology, Fig. 5 Flowchart of PAM and SVSM, and Fig. 6 Flowchart of SI.

Table 3 Sustainability indicators

Source	Economy				Environment						Social		
	E1	E2	E3	E4	N1	N2	N3	N4	N5	N6	S1	S2	S3
Garbie et al. [1]	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤
Helleno et al. [12]	≤	≤	≤					≤					
Garza-reyez et al. [13]	≤				≤	≤		≤	≤				
Choudary et al. [14]	≤								≤				
Gholami et al. [15]	≤											≤	
Hartini et al. [16]	≤	≤	≤	≤	≤	≤	≤				≤	≤	≤
Marie et al. [17]	≤			≤	≤	≤						≤	
Sari et al. [9]	≤			≤		≤	≤				≤	≤	≤
Saraswati et al. [18]	≤			≤	≤	≤	≤			≤	≤	≤	≤
Selected indicators	≤			≤	≤	≤	≤		≤	≤	≤	≤	≤

Economy: Time E1, Cost E2, Inventory E3, Quality compliance and product defect E4
Environment: Material consumption N1, Energy consumption N2, Waste recycle N3, Water consumption N4, Air pollution N5, ISO 14001 compliance N6
Social: Satisfaction employee S1, Work environment: noise level and lighting level S2, Employee training S3

Table 4 Sustainability indicator description

Aspect	Indicator	Unit	*Input*		Calculation	Information
Economy	*Time*	%	VAT	*Value Added Time*	TE = (VAT/TT)100	Processing time from raw materials or materials to finished products
			TT	*Total Time*		
			QE	*Quality Efficiency*		
	Quality Efficiency	%	ND	*Number of Defect*	QE = (1-(ND/TP))100	Product quality efficiency level
			TP	*Total Product*		
Environment	*Material Consumption*	%	ME	*Material Efficiency*	ME = (VAM/TM)100	Amount of raw materials or materials used
			VAM	*Value Added Material*		
			TM	*Total Material*		
	Energy Consumption	Kwh	EC	*Energy Consumption*	EC	The using of energy and resources for the production process
	Waste Water Recycling	%	WE	*Waste Recycle Efficiency*	WE = (WR/TW)100	Reprocessing of water used for the production process
			WR	*Waste Recycling*		
			TW	*Total Waste*		
	ISO 14001 Compliance	%			YES/NO	Environmental standards that have been applied to the company
	Air pollution	%	AP	*Air Pollution*	AP	Air pollution caused by production process/machines
Social	*Satisfaction level*	%	SE	*Satisfaction Employee*	SE	Employee satisfaction in carrying out the activities

(continued)

Table 4 (continued)

Aspect	Indicator	Unit	*Input*		Calculation	Information
	Noise level	NAB			dBl	Noise level consequence by machine used
	Lighting level	LUX			LUX	The level of lighting used in the production process
	Employee Training	%	NT	*Number of Employee Training*	E_HRD = (NT/NE)100	Operator training
			NE	*Number of Employee*		

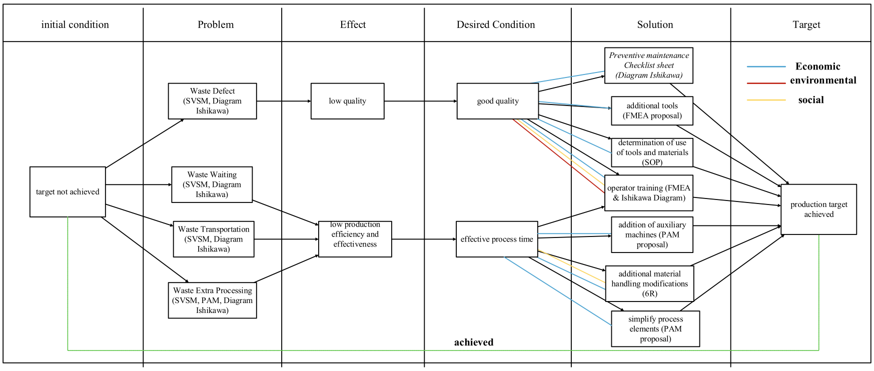


Fig. 3 Research Framework

4 Results and Discussions

4.1 Sustainable Value Stream Mapping and Sustainability Index

Figure 7 presents the current SVSM. The Sustainability Index (SI) calculates the sustainability level across economic, social, and environmental dimensions. The data in Table 5 indicates an SI value of 125.88%.

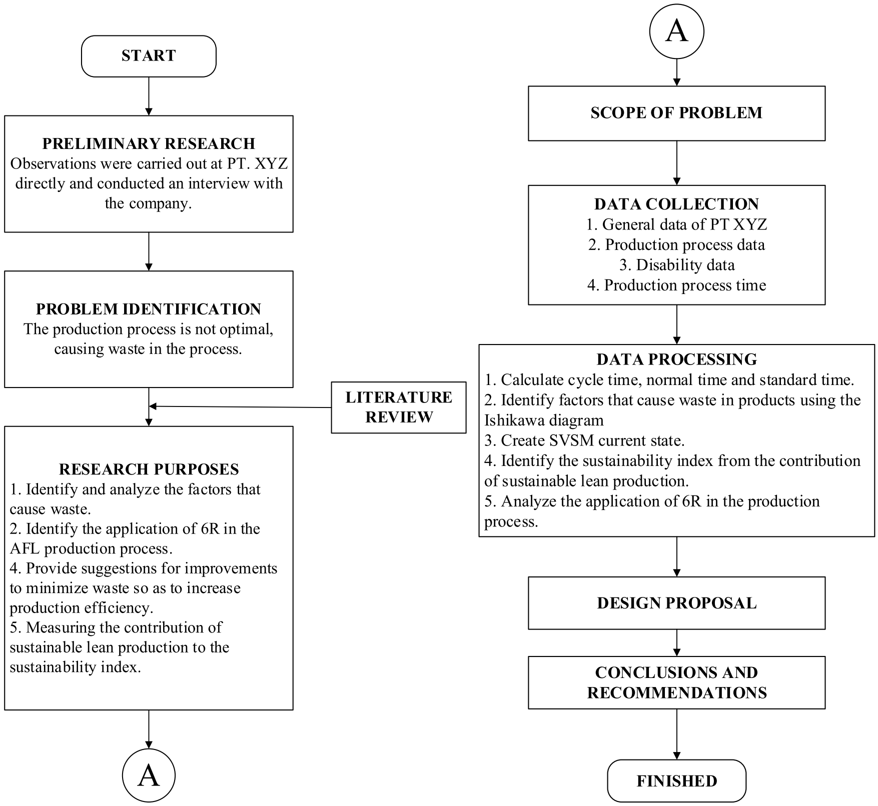


Fig. 4 Flowchart of Research Methodology

Figure 8 shows the future SVSM after implementing improvements (details of improvement see Sect. 4.2). These enhancements include increased efficiency in time management, defect reduction, material consumption, and employee training. Specifically, time efficiency improved by 53%, defect rates decreased to 93%, and employee training effectiveness rose by 92% due to operator training.

As a result of these improvements, Process Cycle Efficiency (PCE) increased by 11%, and quality efficiency improved by 3%. Consequently, production output could increase by 3–4% per month. These proposed improvements help the company more accurately achieve its production targets. Table 6 summarizes these improvements, leading to a projected future SI of 98.87%.

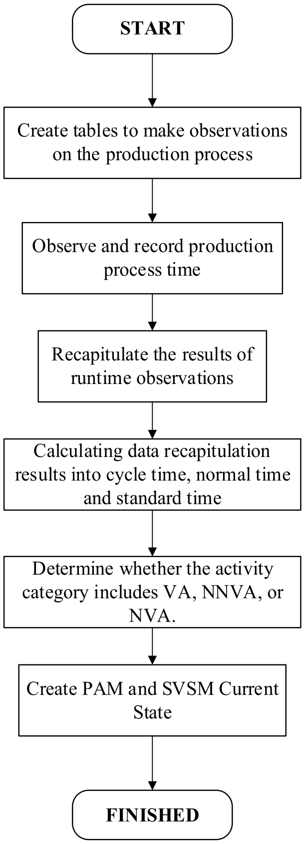


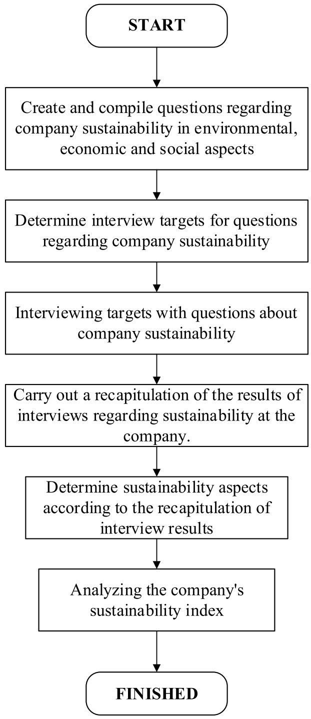
Fig. 5 Flowchart of PAM and SVSM

4.2 Proposed Improvement

The recommendations for addressing defect waste include conducting a Failure Mode and Effect Analysis (FMEA) and performing regular machine inspections using a checklist. Successful implementation of FMEA requires individual awareness and responsibility, as it is a vital tool for quality control. Table 7 presents the proposed corrective actions based on the FMEA results.

Based on the FMEA results, a standard protocol for using tools and materials in production is recommended. Once the tools and materials reach the end of their designated usage period, they should be promptly replaced to minimize machine damage, reducing downtime and defect rates. Introducing a machine inspection checklist will help operators efficiently identify potential machine issues. Operators can ensure consistent performance by systematically checking all machine conditions against the required standards.

Fig. 6 Flowchart of SI



Additionally, the proposed addition of auxiliary equipment targets the cooling process. After careful analysis, it was determined that using the tools listed in Table 7 for cooling can significantly reduce the time needed for shoes to dry. Moreover, the proposed operator training addresses frequent machine downtimes that currently require technician intervention. By providing operators with basic training in handling downtime, the waiting time for repairs can be reduced, especially given the limited availability of technicians and the extended time needed for machine maintenance.

Regarding transportation waste, the recommendation includes introducing modified material handling equipment. Previously, Company X avoided using fuel-powered material handling due to high costs, including fuel and maintenance expenses. Furthermore, the considerable distance between workstations and environmental challenges, such as rain, which can halt operations due to lack of coverage for transported materials, exacerbates the issue. The proposed solution is a rooftop trolley bicycle, which offers a cost-effective alternative with minimal fuel and maintenance requirements and reduces waiting time during transport.

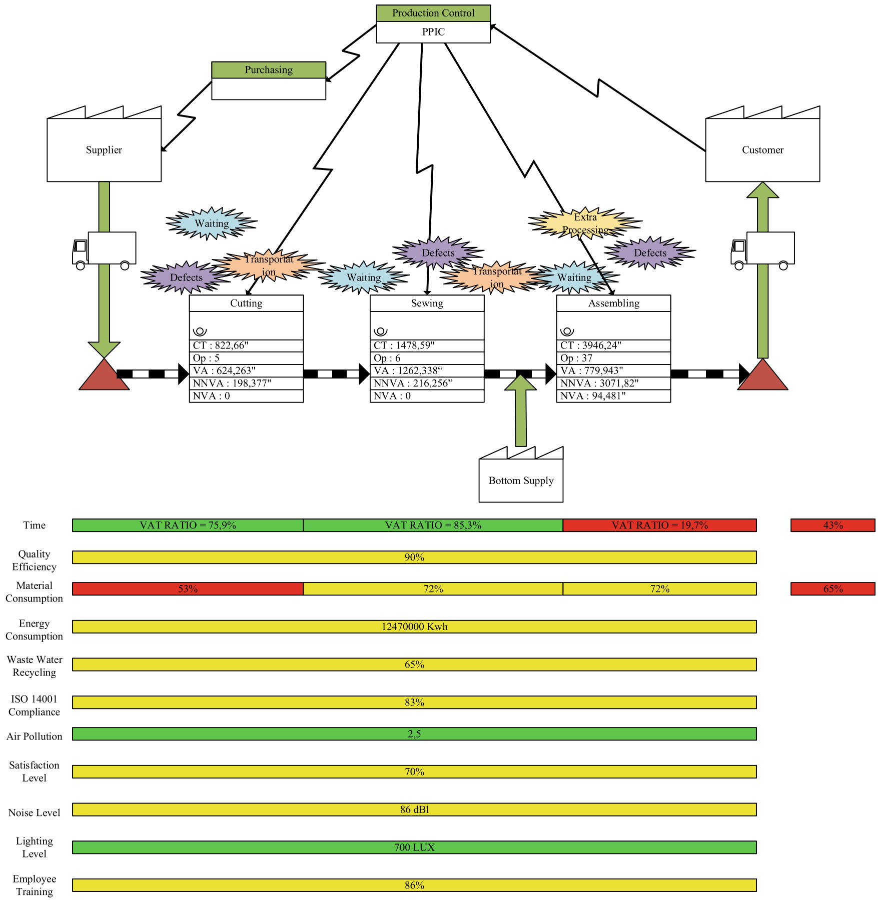


Fig. 7 Current state sustainability value stream mapping

The waste caused by extra processing increases the overall production time. Upon identification, it was found that these processes frequently yield non-standard results. To address this, operators must closely monitor the process to ensure outcomes meet

Table 5 Current value of sustainability indicator

Pillar	Aspect	Indicator	Performance measures	Performance metrics		Value of change
				Existing	Target	
Economy	E11	Time	%	43	50	7
	E12	Quality Efficiency	%	90	100	10

(continued)

Table 5 (continued)

Pillar	Aspect	Indicator	Performance measures	Performance metrics		Value of change
				Existing	Target	
Environment	N11	Material Consumption	%	65	80	15
	N12	Energy Consumption	Kwh	12,470,000	12,000,000	470,000
	N13	Waste Water Recycling	%	85	95	10
	N14	ISO 14001 Compliance	%	83	95	12
	N15	Air pollution	%	2.5	3	0.5
Social	S11	Satisfaction level	%	70	72	2
	S12	Noise Level	NAB	86	85	1
	S13	Lighting Level	LUX	700	750	50
	S14	Employee Training	%	86	95	9

the required standards. The proposed solution for this waste includes streamlining and combining time-consuming activities and aligning the process improvements with the PAM recommendations (Fig. 9).

5 Conclusion

This study identified four types of waste: defects, waiting, transportation, and extra processing. The factors contributing to defects include issues related to machines, materials, human error, and methods. Waiting is primarily caused by human and machine factors, while transportation waste is attributed to human, material, and environmental factors. Human and machine-related factors drive extra processing waste. The PCE based on PAM was 42%. This mapping identified 22 value-added (VA) activities, 23 necessary but non-value-added (NNVA) activities, and three non-value-added (NVA) activities. The breakdown of process types includes 30 operations activities, two transportation activities, seven inspection activities, and nine waiting activities. The SI calculated in this study indicated a company effort of 125.88% towards achieving sustainability.

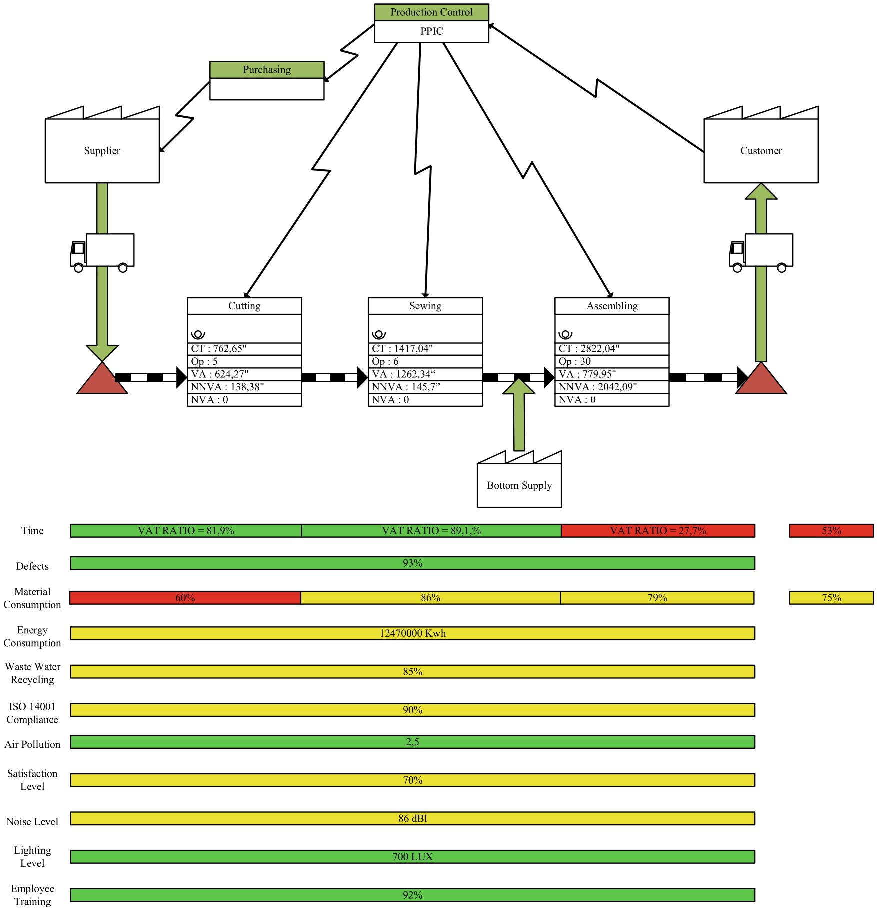


Fig. 8 Future state sustainability value stream mapping

The company's implementation of the 6R concept is structured around the following strategies: (1) Reduction, which involves minimizing waste through pattern mapping and the use of automated machines in the cutting process (2) Reuse, focusing on the reuse of supporting materials (3) Recycling, mainly through the water treatment plant for wastewater management (4) Recovery, which includes repairing cutting molds for reuse and reworking products that do not meet company standards.

Table 6 Future value of sustainability indicator

Pillar	Aspect	Indicator	Performance measures	Performance metrics		Value of change
				Existing	Target	
Economy	E11	*Time*	%	53	50	3
	E12	*Quality Effiency*	%	93	95	2
Environment	N11	*Material Consumption*	%	74	80	6
	N12	*Energy Consumption*	Kwh	12,470,000	12,000,000	470,000
	N13	*Waste Water Recycling*	%	85	95	10
	N14	*ISO 14001 Compliance*	%	90	95	5
	N15	*Air pollution*	%	2.5	3	0.5
Social	S11	*Satisfaction level*	%	70	72	2
	S12	*Noise Level*	NAB	86	85	1
	S13	*Lighting Level*	LUX	700	750	50
	S14	*Employee Training*	%	92	95	3

Several recommendations have been made to support continuous improvement in the production process. These include implementing FMEA-based suggestions, creating checklist sheets for machine inspections, adding auxiliary tools, providing operator training, modifying material handling procedures, applying the poka-yoke method by incorporating automatic temperature detectors, redesigning process activity tools, and summarizing work element activities aligned with the 6R strategy in the proposed activity mapping process. Following the proposed improvements, the PCE increased to 53%. However, the SI improved to 98.87%.

Table 7 Failure Mode and Effect Analysis

Process function	Process standard	Failure mode	Failure effect		Sev	Reason Failure	Occ	Control design		Det	RPN	Suggestion repair
			Next process	Performance product				Control carried out	Detection			
Assembling	Temp: 80–90 C	BPM temperature not in accordance	Sewing process strobel no can conducted	Glue on the material is not melt	6	Thermocouple not working	6	To do checking temperature	Thermocouple	3	108	Always notice timer and temperature conditions machine before the activity process (Using detector temperature automatic)
				Glue on the material is not Becomes hard								
	Time: 25–30″	BPM time no as specified _	Sewing process strobel no can conducted	Material expands	8	Regulator time no working	6	To do checking timer tool	Timer	2	96	–
	Needle: 21 R Tension 20–23	Needle strobel broken	Upper Conditioning no can conducted	There is the hole that doesn't wanted	9	Installation no Correct	5	Wait change needle and rework	Visual	7	315	1. Boost frequency examination (Checklist Sheet) 2. Perform training handling to the operator
						Uneven material cutting _						
						Glue too thick						
		Stitch strobel jump	Upper Conditioning no can conducted	Wrinkle on the upper	7	Needle blunt	7	Wait change needle and rework	Visual	7	343	1. Set standard usage needle 2. Do training handling to the operator
		Stitch strobel pile up	Upper Conditioning no can conducted	Wrinkle on the upper	7	Pitch cup is worn and dirty	7	Wait machine repaired	Visual	7	343	1. Set standard use of pitch cup and needle 2. Do training handling to the operator
						Pully stitching step loose						
	–	Gauge marking is not look	Upper Buffing no can conducted	Toe cup/tip left and right no same	4	Ink congested	5	Rework	Visual	5	100	Provide tool help checking ink

(continued)

Table 7 (continued)

Process function	Process standard	Failure mode	Failure effect		Sev	Reason Failure	Occ	Control design		Det	RPN	Suggestion repair
			Next process	Performance product				Control carried out	Detection			
	Full Cementing Area	Application glue no in accordance with limit glue	Attaching upper and bottom not can conducted	Stain Bond gap or bonding	8	No marking seen	5	Rework	Visual	5	200	To do training to the operator
		Overcement	Attaching upper and bottom not can conducted	Stain Bond gap or bonding	8	Brush glue clot	6	Usage brush scheduled	Visual	4	192	1. Do training to operator 2. Added tool help in the form of separator glue
		Glue about upper	Attaching upper and bottom not can conducted	Stain	8	Hand dirty caught glue	5	Cleaning	Visual	5	200	Add rags on each operator with scheduled
	Pressure: 35–40 kg/cm2	Press bar no appropriate	Delasting no can conducted	Last/ shoes damaged	9	Operator careless	4	Rework and checking parameter settings	Visual	3	108	1. Boost frequency examination (Checklist Sheet) 2. Perform training handling to the operator
	Time: 10–15’	Press bar time is not in accordance	Delasting no can conducted	Bond gap or bonding	6	Operator careless	2	Rework and checking parameter setting	Timer	3	36	1. Boost frequency examination (Checklist Sheet) 2. Perform training handling to the operator
	–	Pad press no appropriate	Delasting no can conducted	Bond gap or bonding	6	Operator careless	2	Rework and checking parameter settings	Visual	3	36	1. Boost frequency examination (Checklist Sheet) 2. Perform training handling to the operator

Fig. 9 Redesigning hand trolley

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