

## Sustainable Lean Six Sigma Competitive Manufacturing Strategy for Luggage Manufacturer

Febriana Lestari<sup>1</sup>, Iveline Anne Marie<sup>1\*</sup>, and Emelia Sari<sup>1</sup>

<sup>1</sup>Faculty of Industrial Technology, Department of Master in Industrial Engineering, Universitas Trisakti, Jakarta, Indonesia.

**ABSTRACT** – International market activities from certification bodies based on customers' request and government policies mandate companies to focus on achieving the right economic goals by paying attention to the social welfare and providing environmentally friendly businesses. Luggage bag companies with plastic raw materials need to increase production efficiency and enhance the quality of goods. The sustainable lean six sigma competitive manufacturing strategy for luggage manufacturer is a driving force for top management of manufacturing companies to apply the operational business concept for product sustainability. Therefore, this research integrated the lean six sigma method with the sustainability concept to validate the strategy for luggage manufactures. This is a case study of a luggage company, carried out by integrating lean and quality management methods in a sustainable manufacturing system to improve the public's assessment. The purpose of this research is to create a framework by integrating the lean six sigma method and applying the sustainable paradigm to the luggage company, to help the company's efforts to meet the requirements of external stakeholders to implement a sustainable production process and solve company problems on efficiency and quality in the production process. The results of this research are to increase production efficiency and improve quality by implementing a lean six sigma competitive manufacturing strategy for luggage companies with sustainable business processes to fulfill the demands from external stakeholders.

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## INTRODUCTION

World leaders from the United Nations, including Indonesia, initiated a global action plan called the Sustainable Development Goals (SDGs) to build better economic, social, and environmental conditions. This is a sustainable program movement that aims to end poverty, reduce inequality, and protect the environment. SDGs focus on the environment with a huge aspiration towards reducing inequality using development as the main tool to capitalize on the change in a sustainable way [1]. These include 17 Goals and 169 Targets expected to be achieved by 2030.

Indonesia continuously participated in the SDGs program in order to improve its welfare by using the country's potential such as educated human resources. The program was implemented, especially in the manufacturing sector, to improve peoples' quality of life in the future. Besides, this sector has the potential to create job opportunities and improve social welfare with a focus on Responsible Consumption and Production, which is the 12th point of the 17 Goals. It is one of the prioritized goals for sustainable development as a whole [2].

The development of international businesses such as companies, education, traveling, and investment is becoming increasingly competitive, which is one of the reasons several people engage in domestic and international migration. However, luggage is a major necessity when traveling because it also serves as a lucrative export commodity for textile products and is the reason luggage bag companies are growing rapidly. The development of this company is extremely influential for economic growth because it absorbs a lot of labor and increases state income because of its export activities. However, it also encounters several problems that have an impact on the company's performance. Previous studies reported that production quality was the main concern of luggage manufacturing companies. Along with global developments, it is important to pay attention to the impact of the company's activities on the social sphere and the surrounding environment.

This research was carried out at a luggage bag manufacturing company. The production process starts with manufacturing the frame, the inner cloth bag, and assembling accessories. Polycarbonate plastic is the main material used to produce luggage bags. However, plastic products take millions of years to decompose, and the rest of the production processes causes environmental pollution. Manufacturers that use this type of materials are considered as those that pollute the environment [3]. The investigated luggage company has a special line that focuses on recycling plastic waste

from leftover production. In simple terms, this consists of a crusher used to grind the waste into plastic flakes and a recycling machine to melt or convert it into pellets. The quality of the resulting plastic is checked to ascertain whether it meets the standard requirements and afterward reused as raw material for the production of luggage bag frames for export recycle commodities. The simple production flow is presented in more detail in Figure 1.

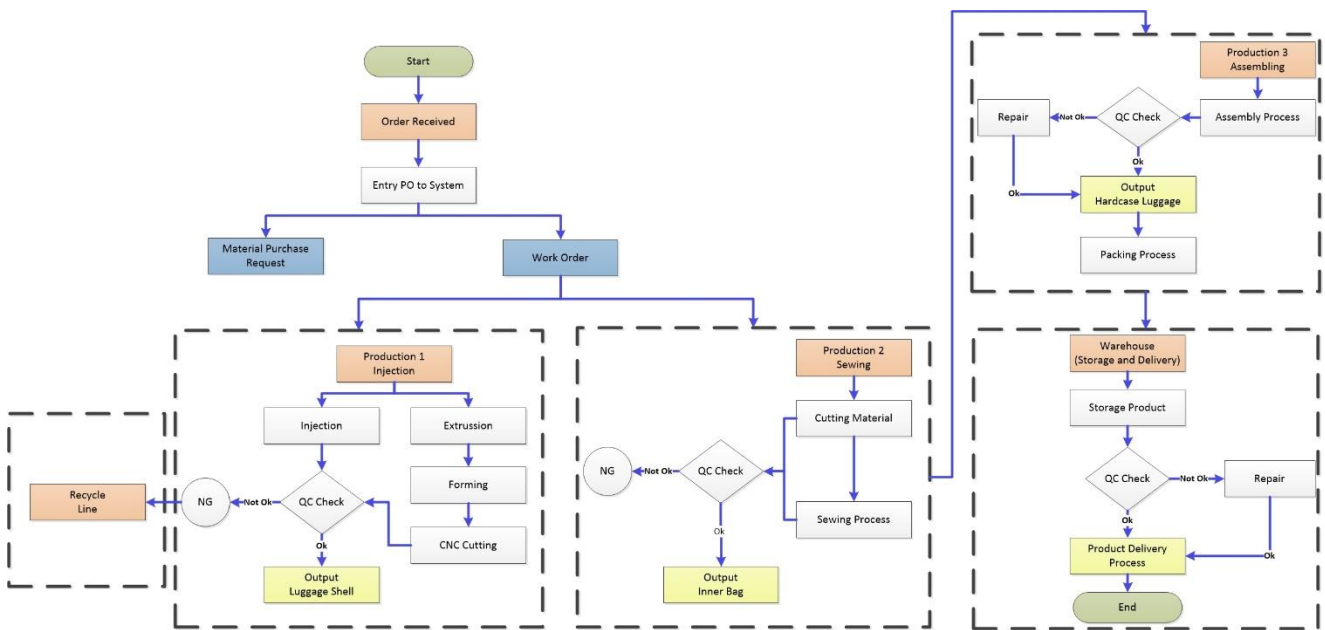


Figure 1: Process Flow of Hardcase Luggage

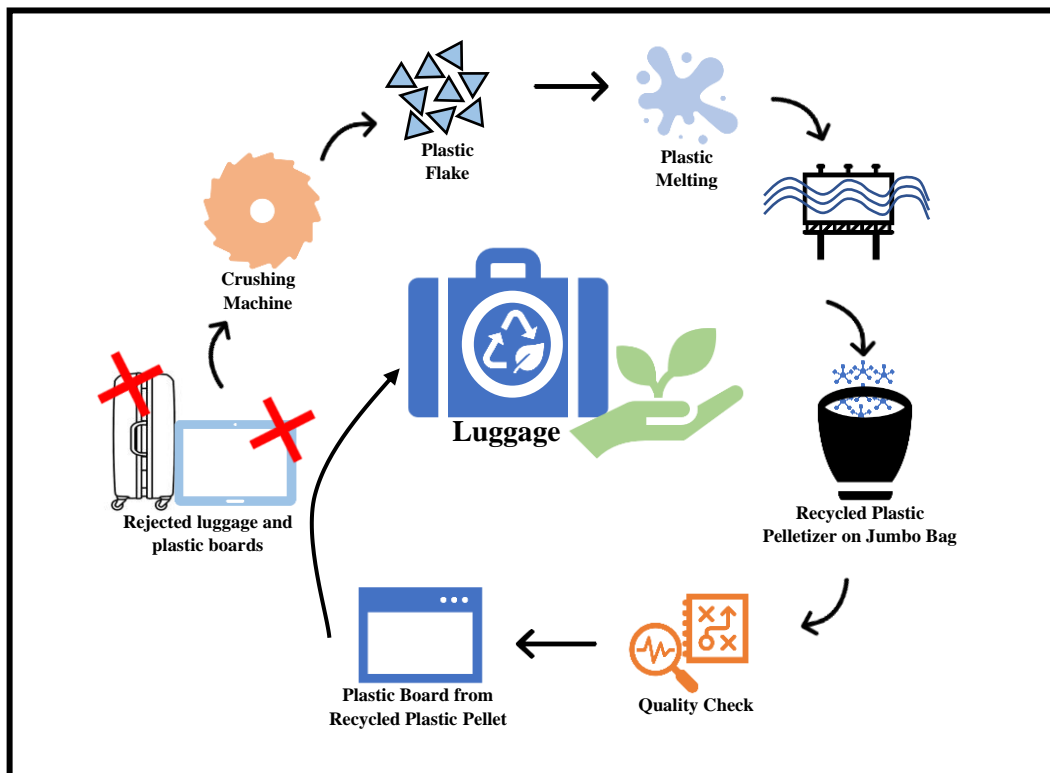


Figure 2: Process Flow of Plastic Recycling Line

Figure 2 describes that company X has a special line to recycle rejected products to ensure they are reused as raw materials. However, this process needs to be controlled because plastic waste has a negative impact on the environment, and its resources are continuously used without offering economic value. Therefore, companies need to adopt environmentally friendly production processes.

Since 2019, customers have requested the implementation of several certifications concerning social and environmental issues by luggage bag companies. This is stated in the sales order contract, therefore these companies are expected to implement the following certifications.

a) GRS (Global Recycling Standard)

It is an international product standard that aims to accelerate sustainable practices in the textile industry in accordance with Social, Environmental, and Chemical requirements.

b) WRAP (Responsible Accredited Production Worldwide)

WRAP is a certification program that independently monitors and ensures that products are manufactured under safe, legal, humane, and ethical conditions. It consists of 12 principles, including compliance with the laws and regulations of a workplace, prohibition of both forced and child labor, harassment or abuse, compensation, and benefits, duration of work, prohibition of discrimination, health and safety, freedom of association, environment, customs, and security. These principles are an effort to achieve the goal of the triple bottom line concept of the sustainability paradigm.

c) Responsible Minerals Initiative (RMI)

It is a standard that needs to be met by smelters and refiners participating in the Responsible Minerals Assurance Process (RMAP).

d) ISO 9001:2015

This is an international certification of Quality Management System.

Customers' demand for this certification is one of the sustainability drivers because it encourages companies to adopt this concept as a marketing tool and a form of awareness involving top management in implementing sustainable movement. The Indonesian Government Regulation on Environmental Permits also mandates companies to prepare an Environmental Management Report every 6 months. Public pressure is one of the key factors influencing the successful implementation of sustainable manufacturing [4]. This has a significant influence on companies because it encourages them to focus on economic benefits as well as pay attention to social and environmental impacts.

Customers are mainly concerned about the luggage bag frame, therefore companies usually try to improve its quality while still prioritizing the production process efficiency. It is made of polycarbonate plastic with leftover remnants or scraps. This company also strives to be responsible for the production process. Therefore, this research assesses the performance of sustainable manufacturing to achieve one of the SDGs 12-point goals regarding Responsible Consumption and Production. It was carried out at the X luggage bag company, which had problems with production efficiency and quality as well as pressure from external parties, as shown in Table 1.

**Table 1:** Quality Report in Production and Warehouse

Month, 2019	Production Quality					Warehouse Product Quality			
	Work Order	Actual Good	Defect Rate $\leq 10\%$			Delivery pcs	QC Rework $\leq 0,1\%$		
			Pcs	%	Result		Pcs	%	Result
July	4480	4480	715	16%	<b>Not achieved</b>	41.337	54	0,13%	<b>Not achieved</b>
August	4100	4100	680	17%	<b>Not achieved</b>	41.302	49	0,12%	<b>Not achieved</b>
September	4120	4120	534	13%	<b>Not achieved</b>	38.641	24	0,06%	Achieved
October	5820	5820	512	9%	Achieved	43.106	64	0,15%	<b>Not achieved</b>
November	6020	6020	582	10%	Achieved	40.421	38	0,09%	Achieved
December	5000	5000	625	13%	<b>Not achieved</b>	48.791	39	0,08%	Achieved

The company applies high product quality standards, therefore the production process allows a defect rate of 10%. In July, August, September, and December 2019, these defects were greater than 10%. A high defect rate is regarded as an economic loss for the company.

The company produces luggage bags based on customers' orders, although they are manufactured in excess in certain circumstances. They are kept in the warehouse and delivered on the date specified by the customer, with a quality check carried out by the Outgoing QC team to ensure product quality before shipping. It allows a rework rate of 0.1% of the total number of items to be shipped. However, it was discovered that in July, August, and October 2019, the product rework was greater than 0.1%. The items with disregard to the delivery date are stocked in the warehouse and are regarded as a waste of production due to the risk of defects.

Previous studies carried out on similar companies stated that they usually apply tools that focus on lean manufacturing to increase economic profits and improve social scope. The research on the application of lean manufacturing by MNC Samsonite South Asia Pvt. Ltd stated that the use of 5S tools saves time in searching for materials and serves as a great cost from unwanted waste and enhances workers' morale due to improved working environment [5]. Therefore, when combined with Overall Equipment Efficiency (OEE) tools, it results in machines' efficient and optimal use, thereby

increasing operation time on the pulley line, the number of products, and performance [6]. Competitive Manufacturing Strategies are related to cost, time, and quality [7] and increases focus on the economic aspect. Meanwhile, this research does not only examine the economic and social aspects, it also investigates quality management and its impact on the environment thereby, ensuring the company’s business processes are sustainable and fulfils external stakeholders’ demands.

The quality inspection aims to fulfil customer expectations, however, this process increases the number of defective products that are regarded as company losses. The application of DMAIC, one of the methods used to improve product quality in the Six Sigma concept, boosts efficiency as well as reacts to any emergent problem [8]. The company's goal is to reduce waste by economizing its resources and increasing profits. Lean manufacturing eliminates waste consisting of components that do not add value to any processes while satisfying customers [9]. Sustainable manufacturing is considered capable of reducing the negative impact of the industry on environmental activities. It also creates a balance between economic, social, and environmental goals [10]. In addition, economic and environmental benefits are obtained from sustainable processes and products [11]. Therefore, the main objective of this research is based on the fact that the company is able to improve production efficiency and product quality by integrating the lean six sigma method and the sustainability concept. To find out more about the development of similar research and the position of this research is described in Table 2.

**Table 2:** Current Research Position

No.	Author	Lean Manufacturing	Six Sigma	Lean Six Sigma	Sustainable Manufacturing	Six Sigma Sustainable	Sustainable Lean Six Sigma
1	[9], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22]	■					
2	[8], [23], [24], [25], [26]		■				
3	[27], [28], [29], [30], [31], [32]	■	■	■			
4	[10], [11], [33], [34], [35], [36]	■			■		
5	[37], [38], [39]		■			■	
6	Current research: Sustainable Lean Six Sigma Competitive Manufacturing Strategy for Luggage Manufacturer	■	■	■	■	■	■

### INTEGRATION OF LEAN AND SIX SIGMA FOR SUSTAINABLE MANUFACTURING

The increasingly competitive international market is the reason companies adopt alternative strategies to integrate profitability, production efficiency, quality, as well as a sustainable goal to achieve customer satisfaction. Production problems and defects are caused by errors at the beginning of the entire process. One of the issues encountered in the manufacturing industry is that products are not always perfect or defective. Therefore, it is important to develop additional strategies to overcome defects [40]. Failure of the company to improve its manufacturing process also causes discrepancies [41]. Defective products are the main focus of Company X and are also regarded as a priority that needs to be eliminated in terms of improving quality because it has no added value.

Six sigma is a method that aids business processes to become more efficient and profitable. It is designed or restructured to maximize customer satisfaction and offer consistent benefits [24]. It is a structured methodology for improving procedures that reduces process variance and product defects [42]. It is also described as a set of proven methods to help companies become more efficient and profitable.

Lean thinking is an approach to achieve superior manufacturing based on sustainable value and waste elimination [15]. An ideal corporate culture drives the success and sustainability of lean transformation in manufacturing [43]. Besides, lean methodology is increasingly being developed and optimized to ensure long-term viability in the business economy. This is based on saving cost, time minimization, internal and external transparency production processes, optimization and simplification of business procedures, and increased production and productivity [14].

Lean Six Sigma is a combination of waste elimination techniques and improved manufacturing processes [30]. The lean concept is the streamlining or efficiency of a process, while Six sigma is defined as a technique that produces not more than 3.4 defective products per million opportunities [29]. Lean Six Sigma is a quality philosophy that uses Lean

management techniques to speed up processes by eliminating non-value-added elements [44]. It describes the concept adopted by companies to minimize waste by reducing the number of product defects and ensuring quality.

Previous research stated that the Lean Six Sigma method is able to minimize waste by reducing product defects. However, this effort is unable to reduce or eliminate certain problems, such as the use of resources and other negative impacts of the production process. Companies need a production performance assessment that covers all aspects. Furthermore, the sustainable manufacturing paradigm is based on the protection of the triple bottom line, consisting of the economy, the environment, and society [45]. One of the company's activities to reduce waste is to minimize the use of resources and increase economic profits. This is in line with the sustainable manufacturing concept's objectives. It is a paradigm that involves the use of effective processes and systems to produce sustainable products, which is becoming increasingly important nowadays [34].

The manufacturing process is aimed at economic profit, society, and the environment. These 3 are considered the main pillars of sustainable development. This concept was designed due to the uncontrolled use of resources for a long time. In addition, the 3 main pillars, including society, economy, and environment, needs to be implemented in a balanced manner.

Sustainable manufacturing needs to be implemented in various industries, thereby helping to further validate and improve efficiency, analyze the sensitivity of the most influential indicators, and obtain a more comprehensive performance assessment at all stages of the production cycle [35]. Six sigma uses the proposed 'weighted defects' to examine the ecological footprint of a problem [38]. However, previous research only focused on the number of defective products by integrating the sustainability concept with the lean and six sigma methods. This research, therefore, improves production quality by adopting lean and six sigma methods and assessing weighted defects on sustainable manufacturing performance. This list of similar researches which will be explained in Table 3 regarding the list of previous research.

**Table 3:** Previous Research List

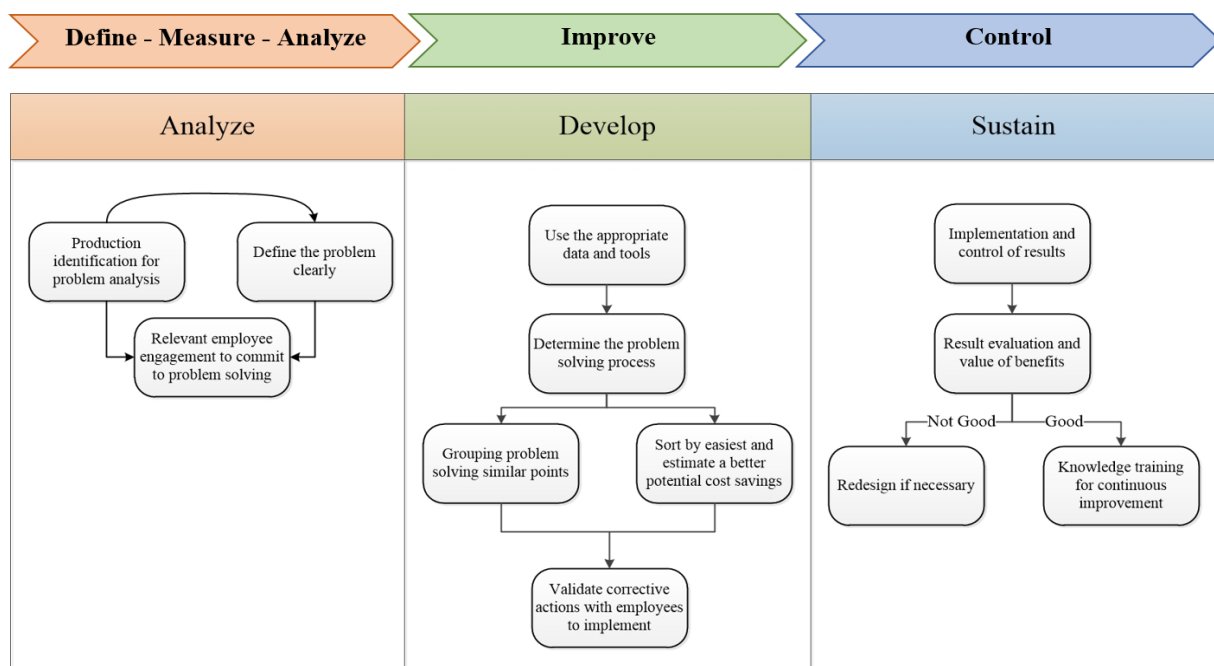
Authors	Research	Objectives
[28]	Green Lean Six Sigma and Financial Performance in Malaysian Automotive Industry	To build an effective model that demonstrates the relationship between Green Lean Six Sigma (GLSS) and Financial Performance (FP) in the Malaysian automotive industry
[29]	Improving Performance of Biscuit Production Process Through Lean Six Sigma at PT XYZ	To analyze loss by adopting a 7-waste approach and NNVA activities during the production process at PT. XYZ, to evaluate its capability and value using Lean Six-sigma, DMAIC technique (Define, Measure, Analysis, Improvement, and Control), and Failure Mode and Effect Analysis (FMEA)
[30]	Lean Six Sigma Implementation in Textile Industry	Proposing a Lean Six Sigma framework to reduce defects that occur in the final product
[32]	The application of Green Lean Six Sigma	Implementing Green Lean Six Sigma as cleaner production. In realizing this, the Define, Measure, Analyze, Improve, and Control (DMAIC) process, which is one of the Six Sigma methods, is used to systematize the Green Lean Environment-VSM tool.
[35]	Manufacturing sustainability assessment using a lean manufacturing tool	Developing sustainable manufacturing index (MSI) based on the lean concept using sustainable-value stream mapping
[38]	Quality management for sustainable manufacturing: Moving from number to impact of the defects	Shifting the focus from the number to the severity of the defects. Develop important concepts related to the integration of sustainable quality management (QM)
[39]	DMAIC-based approach to sustainable value stream mapping: towards a sustainable manufacturing system	Developing a DMAIC-based approach that is effectively applied to systematize Sustainable-VSM.
[44]	Knowledge-based Lean Six Sigma maintenance system for sustainable buildings	Developing a knowledge-based system (KB) to maintain Lean Six Sigma (LSS) in environmentally friendly buildings.
[59]	Design of Sustainable Value Stream Mapping to Improve the Sustainability Indicator: Case in MDF Company	To design the 3 aspects of a sustainable-VSM in the plywood company.

## METHOD IMPLEMENTATION PROCEDURE

The research method was carried out by identifying the conditions and problems faced by the company. Its implementation makes it easier to draw conclusions that adapt to the needs of the company and are validated by applying case studies. The implemented approach compares and validates the company's previous conditions using the sustainable lean six sigma method is to obtain the research output.

The method implementation procedure is based on the following stages "Analyze, Develop, Sustain" [46]–[49] as presented in Figure 3. The analysis stage includes identifying the production floor to determine problems and opportunities by considering employee commitment. The development stage includes data determination, required tools, problem-solving processes, similar grouping suggestions, sorting based on the level of ease, estimating cost savings, and validating corrective actions of employees. The sustain stage includes implementing, controlling, evaluating results, valuable benefits, redesigning when necessary, and providing training for sustainable improvement. Furthermore, preliminary studies reported that production employees need to address quality issues that affect sustainable performance. The tools used for the problem-solving approach are lean techniques integrated with six sigma to prevent and identify social and environmental impacts needed to assess sustainable manufacturing performance.

**Figure 3:** Flowchart of Method Implementation Procedure



The procedures or methods adopted to improve product quality by minimizing waste and implementing sustainable manufacturing activities are regard as the research output. Focusing on environmental impact and sustainability dimensions, quality-oriented manufacturing leads to an increase in the value of the garment as well as product lifespan [50]. Building a sustainable manufacturing system aims to reduce energy consumption, minimize waste, increase product durability and quality, reduce environmental and health problems, including developing renewable energy resources [51].

DMAIC is applied in a lean environment to achieve bottom-line results, which is an aspect of the sustainable paradigm [30]. It is effectively applied to systematize VSM towards sustainable manufacturing [39]. The DMAIC-based approach systematizes the Environment-VSM and increases its efficacy to achieve environmental sustainability [32]. The application of its framework on sustainable manufacturing is used as an approach to identify and eliminate defective products, thereby ensuring that companies enhance their processes and quality through a more sustainable improvement.

### Step 1: Define

In the first stage of the DMAIC method, the problems, goals, and processes are defined to obtain a higher sigma value [23], [25], [31]. The problem is defined by clarifying the production floor objectives and their scope.

The sustainable assessment ensures that the best decisions are made as they are assessed based on sustainable impacts. Its success is realized using indicators that are clearly defined by the objectives and scope of sustainable assessment (SA) [35]. This is one of the most complex types of methodologies because it covers both multi-disciplinary aspects (environmental, economic, and social) and lean production.

A survey method was used to select the indicators by distributing assessment questionnaires to experts in the luggage bag production process. This helps to generate a clear level of awareness and opinion based on experiences therefore, the information needed for the selection of indicators is unbiased. The respondents were selected based on :

- a) Experts in the category with more than 2 years of work experience,
- b) Experts in the category of Supervisor and Manager positions,
- c) Knowledge of the production process flow of luggage bags,
- d) The effect of indicators on the resulting manufacturing.

The indicator design was sent through a google form link to 20 experts that fulfilled the criteria. The questionnaire is a description of general company information and a set of indicators. The google form contains an explanation of ways to fill out the questionnaire and other descriptions regarding the integration of the lean six sigma method with the concept of sustainability.

The selected economic indicators are based on lean manufacturing methods, such as time, inventory, quality (defects), and cost. The score is a reflection of the aforementioned variables [36]. The waiting time of the production process causes a decrease in the inventory, while product failure results in losses. However, when a company focuses on business processes, net income, tax liability, and operating costs, it shows an awareness of economic indicators.

The implementation of sustainability certification is expected to support companies to improve workforce skills, use efficient resources, and environmentally friendly production processes. Its demand takes on the role of guiding consumers and the general public in making sustainable product choices [52]. Participation in implementing a certification scheme reduces the use of irrigation water and other environmental stresses [53]. However, developing a system also includes cooperation between academia and business, as both parties have the best interest of sustainable materials, methods, and technologies [54]. Sustainability certification is considered as one of the important tools to implement targets related to sustainable development from the public or private sector in order to support companies to increase their economic, social benefits as well as preserve the environment therefore, it has an impact on manufacturing performance. Furthermore, the economic indicators used are production time, quality, cost, certification, and government requirements.

The social indicator is based on employees' benefits, such as satisfaction level, safety, health, and providing training. Production managers need to ensure technological improvements and enhance environmental training of workers to reduce consumption and increase profits [55]. Regarding the social impact, maintenance makes it possible to minimize stress, increase trainings on new factory technologies, develop careers, increase work accuracy and motivation [56]. It is the concern and effort of the company to improve the welfare of employees because they are also quality controllers in the production process.

Companies need to comply with established environmental regulations and policies. This is because its operations have an impact on the environment, such as the use of production materials, energy, and water consumption, including hazardous waste. Energy audits on industrial activities are needed to reduce the increasing costs due to its consumption and also for a sustainable future [57]. Meanwhile, assuming the company is able to control its environmental impact, this simply means that it has made efforts to fulfill the certification body's requirement that consumers desire as well as government regulations. The right lean six sigma method with the sustainability concept produces a better output, thereby improving operational and environmental performances [27].

The next stage is to classify all identified indicators based on sustainability aspects. The experts were asked to rate the relevant indicators. The rating scale used was 1 = Very Important, 2 = Fairly Important, 3 = Important, 4 = Unimportant, 5 = Very Unimportant. The results showed that the relevant indicators for the luggage bag company used to design the lean six sigma method for assessing sustainable manufacturing performance are described in the Table 4.

**Table 4:** Relevant indicator for sustainable manufacturing

Aspect	Indicator for sustainable manufacturing
Economic	Time [35], [36], [58], [59],
	Quality (Defect) [38], [36], [59], [60], [61], [62],
	Cost [35], [36], [55], [58], [61], [62], [63],
	Certification and Government Requirement [52], [53], [54]
Social	Satisfaction Level [35], [55], [64],
	Safety Level [35], [36], [55], [58], [59], [61], [63],
	Healthy Level [35], [36], [55], [58], [59], [61], [63],
	Employee Training [35], [36], [58], [61], [62].
Environment	Material Consumption [55], [58], [59], [61], [63], [65],
	Energy Consumption [55], [61], [63],
	Water Consumption [36], [58], [61], [65],
	Hazardous waste [36], [55], [58], [61], [62], [63].

## Step 2: Measure

This stage is carried out by calculating the manufacturing and process lead time, process cycle efficiency, and DPMO to obtain the sigma value. A certain quantity and type of defective products are greatly affected. The measuring stage includes using the defects and existing DPMO (Defects per Million Opportunities) percentage to calculate the sigma value [25]. Good quality and a sustainable process are needed. Six Sigma calculations are carried out by simply counting the number of defects, however, various types have different impacts on a sustainable system. The use of weighted defects helps in integrating quality management with sustainability efforts [38]. To find out more about the formula conventional sigma value and the sigma value based on the impact weight on sustainable performance, it is explained in the Table 5. This stage utilizes several tools related to quality improvement, waste minimization, and sustainable assessment. These are adopted for making sustainable improvements to reduce variations in processes or product defects to fulfill and satisfy customers' expectations.

Sustainable-VSM aims to monitor variability in terms of time, use of resources and assess manufacturing performance on economic, environmental, and social aspects. DPMO is used to measure sigma capability or assess the quality of a process because it is directly related to defective products. The sustainability index is used to determine the value of each sustainable aspect till it reaches the optimal point of impact on each other.

The main purpose of VSM is to document the current state, showing the way and manner the process flow occurs and stops. This research adopted sustainable-VSM, which helps companies to have a better understanding of the production flow process. This method also shows the company's performance from the various aspects that have been determined in the previous stage. It is able to describe the energy use and waste of the manufacturing process [66]. The implementation of the entropy mathematical model based on LESSVSM (Lean-Energy-Six Sigma Value Stream Mapping) in previous studies also disclosed that it was able to reduce the number of rejections and rework, which was a waste [67].

The sustainable-VSM assessment system is made in conjunction with the traffic light system to determine whether an indicator needs improvement [35]. Integrating lean manufacturing tools, particularly with sustainable-VSM, is used to describe the value flow mapping for all processes, activities, values, and information throughout the process and to identify potential areas for improvement and opportunities for waste reduction [39].

**Table 5:** Six Sigma Framework

DPMO and Sigma Level		
Stage	DPMO in Conventional Six Sigma [23]	Weighting Defects in the DPMO Framework [38]
1	$DPO = \frac{\text{The number of defects found}}{\text{The number of units examined} \times \text{number of opportunities per unit}}$ $DPMO = DPO \times 1.000.000$	$\text{Weighted DPMO} = \frac{\text{Total weight of defects} \times 10^6}{\text{Total opportunities in each unit} \times \text{total unit}}$
2	For calculating the sigma values using Microsoft Excel with the formula : $\text{Sigma Value} = \text{NORMSINV} \frac{1.000.000 - \text{DPMO}}{1.000.000} + 1,5 \quad [26]$	

## Step 3: Analyze

Analyze stage aims to determine the potential causes of defects; therefore, ascertaining improvements are proposed according to the target. After determining the current conditions of the sustainable-VSM, the next stage in the proposed approach refers to the analysis, interpretation, and proposed strategies for the identified waste elimination or minimization processes [39]. The production process was further observed from the sustainable-VSM data. In the analysis stage, the lean approach was used to examine the waste from each aspect. The sustainability concept adopted in the manufacturing process through the VSM integration and sustainability indicators effectively contributes to its improvement, although this is still in the developmental stage and requires further analysis [68]. Previous research stated that the VSM was able to improve the sustainability performance of the iron and steel industry by providing transparent information through visualized mapping of actual and future conditions. This was realized by supporting decision-making programs to prioritize industrial waste management and treatment system components, promoting a zero-waste footprint [69]. Furthermore, the ability to analyze defective products indicators and material consumption in sustainable-VSM aid in identifying potential waste in the production process [70].

In terms of six sigma major defects were analyzed based on production reject reports using the Pareto diagram. Several previous studies have used the diagram to detect the highest defects [30], [71], [72], [73], [74]. It is an important tool for significant early identification by showing the prioritized defects that need urgent repairs [75].



Furthermore, the causes of waste are analyzed by sketching a cause and effect diagram, which is extremely useful in detecting the emergence of nonconformities in the form of excessive process variations however, it is unable to show the cause of deviations [75]. The data analysis phase related to the root causes of waste in this research applied the information from experts and held detailed discussions about high defects, waste, and resource consumption. The participants are production managers, leaders, experienced operators, QC, and maintenance teams. This discussion revealed the various causes to produce continuous corrective actions. A brainstorming session to develop a cause and effect plot results in actions to address the prioritized problems [76].

#### Step 4: Improve

This stage aims to improve problems based on data processing [23]. The identified and implemented corrective actions tend to be visualized with a future-state sustainable-VSM that represents operational activities as desired. This improvement stage takes corrective action against the dominant waste after identifying the cause. The waste elimination input formulated in the previous phase describes the improvement made by the value process flow achieved through developing future-state sustainable-VSM [39]. This determines the efficiency of the expected corrective actions.

Efforts to improve quality are monitored by calculating DPMO to generate new sigma values. The results are evaluated to determine the efficiency and significant effect. Sustainable performance assessment is carried out by comparing the scores of each indicator with the target and the existing ones. Sustainable-VSM is used for indicator assessment, therefore the sustainable manufacturing index tends to be controlled periodically after implementing corrective actions [35].

#### Step 5: Control

The control stage is used to confirm whether the changes implemented from the corrective actions are sufficient and sustainable by verifying the quality of the improved process [8]. Statistical Process Control (SPC) with Minitab helps in monitoring, controlling, and maintaining improvement activities. The analysis phase of the improvement results uses this tool to improve Six-Sigma quality [77]. SPC is a quality management technique used to collect and analyze data easily, it also enables continuous performance monitoring and quality improvement, the ultimate goal of which is to increase profitability [78]. This tool describes statistical techniques in monitoring and improving quality in the production process [79]. However, by using the SPC, verified and monitored data from implementing corrective actions are visualized through the design of control chart tools and minimum or maximum limit parameters. This process ensures the efficiency of corrective actions implemented by all employees during the process.

## RESULT

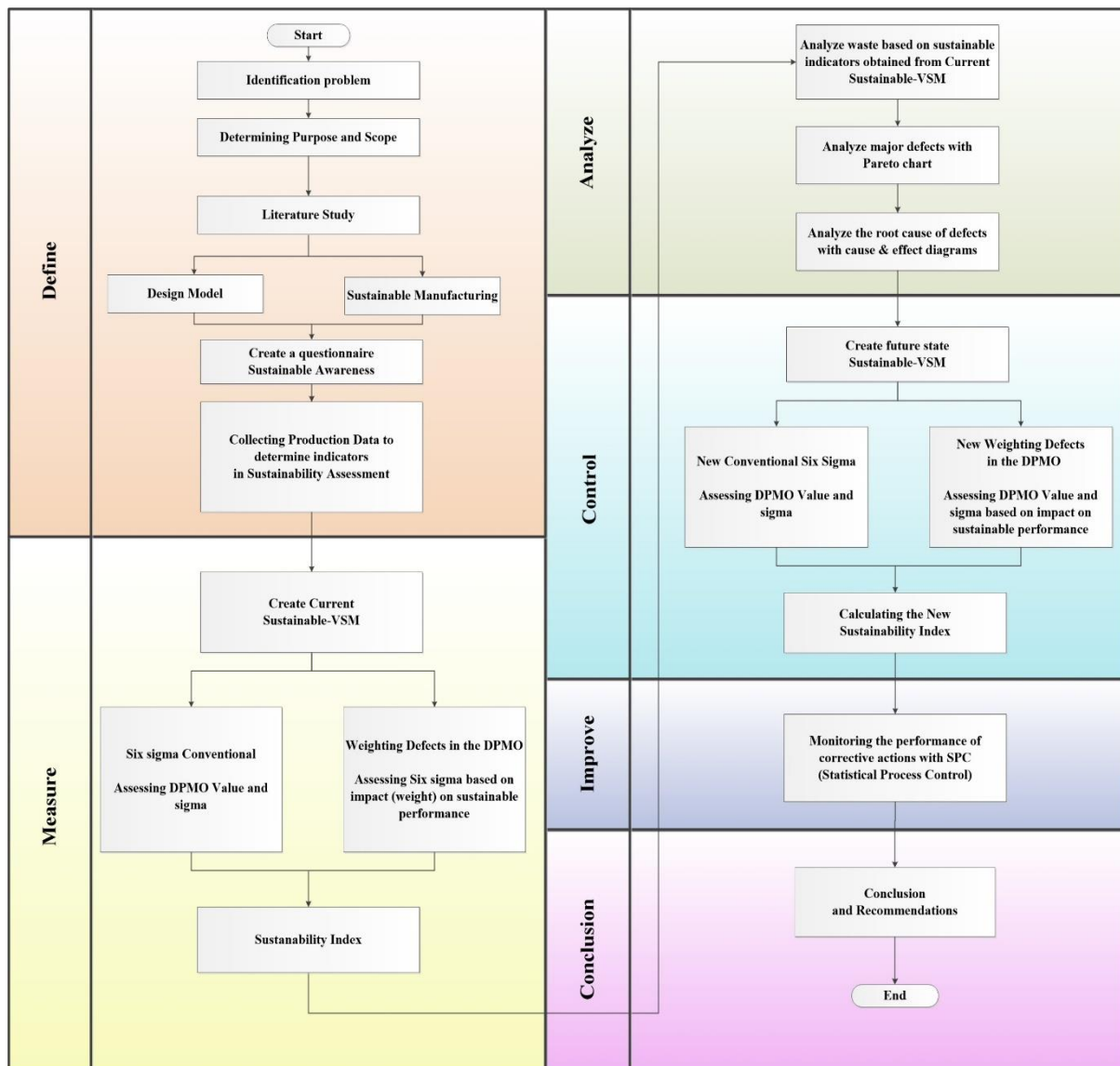
This research examined the efforts to improve production efficiency and product quality to develop more sustainable business processes. The framework was created using the sustainable integration of the lean six sigma method and validated by proving its application in a case study of a luggage company. The efforts to encourage business processes to be more sustainable are in line with customer requests through certification bodies. They can meet the Indonesian Government Regulations related to social welfare and environmental preservation. The results of the research are a sustainable lean six sigma research framework as described in detail in Figure 4.

## CONCLUSION

The developing company is focused on both economic benefits and business processes for the long term. It is expected to maximize the method proposed in this study. Furthermore, the research resulted in an analysis that confirmed that the sustainable lean six sigma method increased production efficiency, product quality, awareness to become a more sustainable company and earned public trust. This research applied 12 indicators used to :

1. Improve the lean aspect by minimizing production waste, including those that have an impact on sustainable performance
2. Improve product quality by assessing each defect based on its impact on sustainable performance
3. Generally assess sustainable manufacturing performance from each aspect

Therefore, the company tends to improve business processes following the sustainable concept and support efforts to fulfill stakeholders' demands. Further research is expected to apply the proposed method to other case studies from various types of industries to ensure its validity. This method requires the selection of indicators and weights of the most influential defects types in each production process to improve the quality and assessment of sustainable company performance.



**Figure 4.** Sustainable Lean Six Sigma Research Framework

The limitations of this research lie in the indicators and weights of the defects types used, therefore, as the company's business develops, this assessment needs to be reviewed within a certain period. These 2 aspects are definitely different in industries. Therefore, it requires further analysis in the future. Furthermore, the goals and commitments of each company are also different. Besides, further investigation is also expected to maximize the proposed method in accordance with the company's goals and commitments. In this study, the method that has been applied has reached the defined stage, further research can maximize research methods to validate the proposed framework.

This method is able to increase the sustainability awareness and commitment of top management to generate a company with sustainable business processes. It fulfilled the requirements of certification bodies according to customer requests and government regulations. The research method was applied until the company was able to show more sustainable business processes by using the sustainable-VSM tools. Therefore, future research needs to maximize the proposed method by using relevant defect indicators and findings.

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