

# Integrating Fuzzy-AHP–Based Lean Tools and Six Sigma–FMEA for Defect and Lead Time Reduction in Creative Industry SMIs

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## Abstract

*The expansion of the creative industry in Indonesia has intensified competitive pressure on manual-production-based SMEs, making process efficiency and product quality critical factors in maintaining competitiveness. At Gendhis Natural Bag, observations revealed that non-value-added activities accounted for 38% of total production time, with a lead time of 6,527 seconds and a defect rate of 15,183.73 DPMO. These conditions indicate that the challenges faced are not only related to process flow inefficiencies but also involve product quality issues, necessitating an integrated improvement approach to systematically identify, prioritize, and reduce waste. This study proposes an integrated lean improvement framework by combining Value Stream Mapping (VSM), VALSAT, Kaizen 5S, and Six Sigma–FMEA, while Fuzzy-AHP is used to objectively determine waste priorities. The research findings indicate that defects are the most critical form of waste, while PAM identified that 38% of total production time consists of non-value-added (NVA) activities, which are dominated by delays and setup time. Based on the improvement plan using the Kaizen 5S approach, production lead time is projected to decrease from 6,527 seconds to 4,377 seconds, with the potential to increase output from 30 to 42 units per day. Additionally, the proposed quality improvement using the Six Sigma–FMEA approach is estimated to reduce the DPMO value from 15,183.73 to 8,928.57 and increase the sigma level from 3.69 to 3.87. These findings indicate that the proposed integrated improvement framework has the potential to enhance the efficiency and quality of the production process and can serve as a relevant approach for SMEs with manual production systems.*

**Keywords:** Creative Industries, Fuzzy-AHP, Lean Tools, Six Sigma, SMIs

## 1. INTRODUCTION

In the modern era, economic performance has become one of the key indicators of national development, with the creative industry playing an important role in generating added value, employment, and economic growth. In Indonesia, the creative industry has shown significant growth, contributing IDR 989.1 trillion in 2017, increasing to IDR 1,066 trillion in 2018 (Setiawan, 2018), and reaching IDR 1,153 trillion in 2019, while absorbing approximately 19.2 million workers or 15.21 percent of the national labor force (Loeis et al., 2023). Among the rapidly growing sectors promoted by the government are fashion, culinary arts, and handicrafts (Munaf, 2026). The development of this sector encourages business actors to improve innovation, production capability, and market competitiveness to sustain their advantage in increasingly competitive markets (Muhyidin & Istimal, 2022) (Kemendag, 2007).

To remain competitive, many firms adopt lean manufacturing practices to minimize waste and improve operational performance. Lean manufacturing not only reduces inefficiencies but also enhances competitiveness in terms of quality, cost, delivery, and flexibility (Khannan & Haryono, 2015). This issue is particularly relevant

for small creative enterprises such as Gendhis Natural Bag, a home-based handicraft business in Yogyakarta producing handmade natural-fiber bags. The company still relies heavily on conventional production methods, which increases the risk of inefficiencies such as waiting time, rework, and duplicated activities, all of which contribute to operational waste (Blijleven et al. 2017). Such waste, including overproduction, unnecessary inventory, overprocessing, unnecessary motion, waiting, defects, and transportation, can significantly reduce organizational efficiency (El-Namrouty & AbuShabaan, 2013). A study by Indrawati et al., (2022) how that reducing waste through lean approaches can improve productivity, reduce lead time, and lower operational costs.

One effective approach to minimizing waste is lean manufacturing, which focuses on eliminating non-value-added activities while creating greater value with fewer resources (Fernando & Noya, 2014)(Womack, et al., 1991). Among the commonly used lean tools, Value Stream Mapping (VSM) helps visualize material and information flows within the production system, while Value Stream Analysis Tools (VALSAT) provides detailed mapping techniques to identify critical sources of waste and inefficiency (Steur, et al., 2016). However, previous studies rarely integrate VALSAT with decision-support methods such as Fuzzy Analytical Hierarchy Process (Fuzzy-AHP) to prioritize waste systematically. Moreover, limited research combines process improvement tools such as Kaizen 5S with quality improvement methods such as Six Sigma-FMEA in a single integrated framework, especially in creative industry SMEs.

Therefore, this study aims to develop an integrated lean improvement framework for reducing waste and improving operational performance in creative industry SMEs, specifically at Gendhis Natural Bag. The framework combines Fuzzy-AHP for waste prioritization, VALSAT for process diagnosis, Kaizen 5S for workflow improvement, and Six Sigma-FMEA for defect reduction. This integrated approach is expected to provide a systematic and data-driven strategy to enhance productivity, minimize waste, and improve product quality in highly manual creative manufacturing environments.

## 2. RESEARCH METHODOLOGY

This research uses a case study approach to analyze the production system at Gendhis Natural Bag in depth and within its real operational context. This method is suitable for examining manual, dynamic, and interconnected production processes, allowing the identification of inefficiencies through direct observation and process mapping. The research procedure is carried out through six structured stages.

### 2.1 Stage 1 – System Identification

The first stage involves identifying the existing production system through direct observation of the main production activities, namely cutting, sewing, gluing, and finishing. This stage aims to obtain an initial understanding of the workflow, labor utilization, and production conditions as the basis for waste analysis.

### 2.2 VALSAT Analysis and Tool Selection Framework

A systematic literature review was conducted to examine Value Stream Mapping (VSM) and Value Stream Analysis Tools (VALSAT), including PAM, SCRM, QFM, PVF, and DAM, in identifying waste within production systems. Hines & Rich (1997) explain that these tools help detect different types of inefficiencies in

value streams and support the selection of appropriate mapping methods based on system conditions.

VSM is recognized as a lean manufacturing tool that captures cycle time, resource usage, inventory, and information flow, enabling the distinction between value-added and non-value-added activities (Singh et al., 2011). It has also been shown to effectively identify bottlenecks, reduce lead time, and improve process efficiency, particularly in manual and high-variability production environments (Abdulmalek & Rajgopal, 2007)

Overall, this review provides a foundation for selecting suitable VALSAT tools for SMEs and supports the development of an evidence-based framework tailored to the operational characteristics of Gendhis Natural Bag.

### *2.3 Stage 3 - Data Collection for VALSAT and VSM*

Primary data were collected to support the implementation of VALSAT and the development of the current-state VSM. The collected data include process flow, processing time, waiting time, operator activities, and material movement.

### *2.4 Stage 4 - Development of the Current State Map*

Based on the collected data, the current-state value stream map was developed to visualize the flow of materials and information throughout the production process. This stage is used to identify waste sources, delays, and non-value-added activities.

### *2.5 Stage 5 - Waste Prioritization Using Fuzzy-AHP and VALSAT Weighting*

The identified waste categories were prioritized using Fuzzy-AHP to determine the relative importance of each waste type. The resulting weights were then used to evaluate the suitability of the VALSAT tools and to select the most relevant tools for detailed analysis.

### *2.6 Stage 6 - Lean Improvement Analysis and Future-State Design*

The selected VALSAT tools primarily PAM and QFM are then used for detailed analysis based on the highest weighting scores obtained from the Fuzzy AHP and VALSAT evaluation.

- PAM is employed to identify non-value-added activities, such as unnecessary motion, delays, excessive setup time, and inefficient workplace organization,
- QFM is used to detect and categorize quality-related defects throughout the production flow. The defects identified through QFM are further evaluated using Six Sigma metrics and Failure Modes and Effects Analysis (FMEA) to quantify defect severity, occurrence, and detectability. Based on the findings from PAM and QFM, improvement initiatives are then formulated using the Kaizen 5S approach to eliminate inefficiencies, improve workplace organization, and enhance quality performance.

Through these integrated stages, the methodology systematically connects waste identification, quantitative prioritization, process analysis, and improvement implementation providing a rigorous and replicable framework for operational enhancement in craft-based SMEs.

## **3. RESULT AND DISCUSSION**

### *3.1 Current Condition and Waste Identification*

The initial analysis of the production process at Gendhis Natural Bag revealed that the existing workflow still contained substantial non-value-added activities that

reduced operational efficiency. Using Process Activity Mapping (PAM), production activities were classified into value-added (VA), necessary but non-value-added (NNVA), and non-value-added (NVA) categories. As shown in Table 1, only 58.28% of the total lead time was categorized as value-added activity, while 38.19% consisted of non-value-added activities.

The high percentage of non-value-added activities indicates that a significant portion of the production time was spent on activities that did not contribute directly to product value. These inefficiencies were primarily found in adhesive preparation, waiting for glue drying, repeated movement between workstations, and unnecessary setup activities. Such delays prolonged the production lead time and reduced labor productivity.

**Tabel 1** Current State Activity Distribution

Activity	Time (sec)	Percentage (%)
Value Added	3804	58.28%
Non Value Added	2493	3.52%
Necessary but Non Value Added	230	38.19%
Total	6527	100.00

The current-state value stream map shown in Figure 1 confirms that the dominant sources of waste were concentrated in the sewing and gluing processes. These stages experienced frequent waiting times and operator movement delays, which created bottlenecks and increased the total production lead time.

### 3.2 Waste Prioritization

To determine the most critical waste categories, Fuzzy-AHP was used to prioritize the seven types of waste identified in the production process. As presented in Table 2, defects had the highest priority weight of 0.49, followed by waiting and inappropriate processing, each with a weight of 0.22.

This result indicates that product quality issues were the most critical source of inefficiency in the production system. In addition, the weighting results showed that PAM and QFM were the most appropriate tools for analyzing the dominant waste categories. PAM was selected to analyze inefficiencies related to waiting and inappropriate processing, while QFM was used to identify and evaluate quality-related defects.

**Tabel 2** Waste Prioritization and Selected VALSAT Tools

Criteria	AHP Weighting	Fuzzy AHP Weighting	Selected Analysis Tool
Defect	0.36	0,49	QFM
Excessive Transportation	0.17	0,17	-
Inappropriate Process	0,17	0,22	PAM
Overproduction	0.03	0,06	-
Unnecessary Motion	0.02	0,03	-
Unnecessary Inventory	0.09	0,13	-
Waiting	0,15	0,22	PAM

The prioritization results demonstrate that operational delays and product defects were the key issues limiting production performance at Gendhis Natural Bag.

**3.3 Improvement Impact**

Based on the identified waste priorities, improvement actions were developed using Kaizen 5S to reduce process waste and Six Sigma–FMEA to improve product quality. The operational improvements focused on workstation arrangement, material placement, adhesive drying efficiency, and sewing standardization.

The impact of these improvements can be seen in Table 3. The total production lead time decreased from 6527 seconds to 4377 seconds, representing a 32.9% reduction. At the same time, value-added activities increased from 58.28% to 86.91%, while non-value-added activities decreased significantly from 38.19% to 5.76%.

**Table 3** Operational Improvement Impact

Activity	Total	Time (Second)	Percentage
Lead Time (sec)	6527	4377	32.9
Value Added (%)	58.28	86.91	49.1
Non-Value Added (%)	38.19	5.76	84.9
Daily Output (units)	30	42	40.0

These operational improvements increased the estimated daily production output from 30 units to 42 units, which represents a 40% increase in productivity. This increase indicates that the intervention not only reduced waste but also enhanced the company’s production capacity without requiring additional labor resources.

Further analysis was conducted to identify the root causes of product defects in the bag production process. This analysis stage employed Failure Mode and Effects Analysis (FMEA) to systematically identify and evaluate risks that may lead to potential failures (Vitho, Ginting, & Anizar, 2013).. The results of the FMEA analysis are presented in Table 4.

**Table 4** Failure Mode Effect Analysis

Item Function	Potential Failure Mode	Potential Effect on Customer Because of Defect	SEV	Potential Causes	OCC	Current Process Control	DET	RPN	Ranking
Accuracy Level	Sewing	The bag becomes easily damaged	7	Inconsistent stitch spacing (F1)	6	Adjust stitch spacing during the sewing process (F1)	4	168	2
				Inconsistent stitch depth (F2)	7	No defined standard for stitch depth during sewing (F2)	8	392	1
	Cutting	Reduced accuracy of bag dimensions	8	Inaccurate cutting based on the pattern (F3)	4	Adjust machine positioning to match	3	96	3

Item Function	Potential Failure Mode	Potential Effect on Customer Because of Defect	SEV	Potential Causes	OCC	Current Process Control	DET	RPN	Ranking
						the pattern shape (F3)			
				Workers are less careful when using the cutting machine (F4)	2	Workers focus on cutting according to the pattern outline (F4)	3	48	4
Aesthetics	Accessories Installation	Reduced aesthetic value of the bag	3	Incorrect accessories installation (F5)	4	Workers should record the type of accessories for each type of knitted bag (F5)	3	36	5

Based on the FMEA (Table 4), the level of risk and its associated impact can be identified through the Risk Priority Number (RPN). The RPN value is obtained from the multiplication of the severity (S), probability (P), and detectability (D) ratings. The FMEA results indicate that the highest RPN corresponds to the sewing defect caused by inconsistency in stitching depth, with an RPN value of 392.

After observing the root causes of defects in the bag manufacturing process, the next step involves implementing improvement actions by determining appropriate solutions to minimize the occurrence of defects. Several improvement proposals to address product defects in bag production are presented in Table 5.

**Table 5 Improvement Solutions for Bag Defects**

Potential Failure Mode	Potential Causes	Improvement
Sewing Sewing	Inconsistent stitch spacing	Use an appropriate sewing machine needle by adjusting it to match the bag size.
	Inconsistent stitch depth	Adjust the needle setting according to the thickness of the bag material.

In the controlling stage, control actions are implemented to reduce the number of defective bag products by comparing the DPMO values and sigma levels before and after the improvement initiatives. Therefore, the researchers propose structured control measures for Gendhis SMEs to ensure that the implemented improvements are consistently maintained.

Quality improvement was also observed after the implementation of Six Sigma-based corrective actions. As shown in Table 6, the DPMO value decreased from 15183.73 to 8928.57, while the sigma level improved from 3.70 to 3.87.

**Tabel 6** Quality Improvement Impact

Condition	DPMO	Level Sigma
Before Improvement	15183,7284	3,69736567
After Improvement	8928,571429	3,868567059

The reduction in DPMO indicates that the number of defects decreased significantly, resulting in lower rework frequency and reduced material waste. Overall, the proposed interventions generated measurable operational benefits by improving workflow efficiency, increasing productivity, and enhancing product quality.

### 3.4 Discussion

The results demonstrate that the integration of Fuzzy-AHP, VALSAT, Kaizen 5S, and Six Sigma–FMEA effectively improved operational performance at Gendhis Natural Bag. The reduction in lead time and non-value-added activities, as shown in Table 3, indicates that the implemented interventions successfully addressed the major sources of inefficiency identified in the current-state analysis.

From an operational perspective, these improvements increased resource utilization efficiency and enabled higher production output within the same working time. This is particularly important for labor-intensive SMEs, where productivity improvements directly affect delivery capability and operational competitiveness.

Furthermore, the quality improvement shown in Table 6 demonstrates that defect reduction initiatives improved process capability and product consistency. Fewer defects reduce the need for rework and lower material losses, which contributes to cost efficiency and customer satisfaction.

Therefore, the integrated lean improvement framework not only identified waste but also generated practical and measurable impacts on productivity and quality performance. This confirms that the proposed approach can serve as an effective strategy for improving operational performance in craft-based SMEs with highly manual production systems.

## 4. CONCLUSION

Based on the results of this study, the following conclusions can be drawn:

1. The integration of Fuzzy AHP and VALSAT proved effective in systematically identifying and prioritizing the most critical waste in the production system of Gendhis Natural Bag. The results showed that defects, waiting, and inappropriate processing were the dominant waste categories, while Process Activity Mapping (PAM) and Quality Filter Mapping (QFM) were selected as the most relevant analytical tools. This finding indicates that combining decision-support methods with lean analysis tools can improve the accuracy of waste prioritization and support more focused operational improvement decisions in labor-intensive SMEs.
2. The application of PAM supported by Kaizen 5S successfully reduced process inefficiencies by minimizing non-value-added activities and improving workflow organization. Production lead time was reduced from 6,527 seconds to 4,377 seconds, while daily production output increased from 28 units to 42 units. These improvements demonstrate that systematic waste reduction can significantly increase productivity and operational efficiency without requiring additional labor

or substantial investment, which is highly beneficial for small manufacturing enterprises.

3. The implementation of QFM integrated with Six Sigma and FMEA improved production quality performance by reducing defect rates and increasing process capability. The sigma level improved from 3.69 to 3.87, while the DPMO value decreased from 15,183.7284 to 8,928.5714. This result shows that structured quality improvement tools can reduce rework, improve product consistency, and enhance process reliability in manual production systems.
4. The implementation of QFM supported by Six Sigma and FMEA improved Overall, this study confirms that the integration of Fuzzy AHP, VALSAT, Kaizen 5S, and Six Sigma provides not only measurable improvements in efficiency and quality but also a practical framework for strengthening the competitiveness of craft-based SMEs. The significance of this research lies in demonstrating that a data-driven and integrated lean improvement approach can help small manufacturing enterprises improve productivity and quality simultaneously, making the framework applicable as a reference for similar SMEs seeking sustainable operational improvement.

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