Reducing Material Loss in Gold Bracelet Production Using Material Flow Cost Accounting and Value Stream Mapping

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DOI: https://doi.org/10.31284/j.jtm.2026.v7i2.9242
Received July 12nd 2026; Received in revised July 20th 2026; Accepted July 20th 2026; Available online July 29th 2026

Abstract

Material loss is a critical issue in gold jewelry manufacturing because it increases production costs and reduces resource utilization efficiency. This study aims to identify material loss and its associated costs using Material Flow Cost Accounting (MFCA), analyze production waste through Value Stream Mapping (VSM), determine the root causes of inefficiencies using a Fishbone Diagram, and develop improvement strategies based on the 5W+1H approach. A quantitative descriptive method was employed using production data from the Morena 12K bracelet manufacturing process at PT XYZ during the period of Desember 2025 to February 2026. MFCA was applied to quantify material flow and classify production costs into positive and negative costs, while Current State Value Stream Mapping (CSVSM) was used to identify value-added and non-value-added activities. The results indicated that material loss fluctuated between 10.39% and 23.06%, resulting in negative costs ranging from IDR 1.07 billion to IDR 2.89 billion. Waste analysis revealed that waiting and defect were the dominant sources of inefficiency, primarily caused by machine downtime, CNC setup, and finishing operations. The proposed improvements, developed using the 5W+1H approach and evaluated through Future State Value Stream Mapping (FSVSM), reduced production lead time from 421.417 minutes to 381.967 minutes and increased Process Cycle Efficiency (PCE) from 35.29% to 42.71%. Furthermore, the Future MFCA evaluation demonstrated a reduction in negative costs and material loss, accompanied by an increase in positive costs, indicating more efficient material utilization and improved production performance. These findings demonstrate that integrating MFCA and VSM is an effective approach to minimizing material loss, reducing hidden production costs, and supporting continuous improvement in gold jewelry manufacturing.

Keywords: *Gold Jewelry, Material Flow Cost Accounting, Material Loss, Process Cycle Efficiency, Value Stream Mapping.*

1. Introduction

The manufacturing industry is required to continuously improve production efficiency to remain competitive in today's business environment. One of the important factors affecting production efficiency is the effective use of raw materials. In the gold jewelry industry, material loss is a major concern because gold has a high economic value. Even a small amount of material loss can increase production costs and reduce company profits. Therefore, controlling material loss is essential to improve production performance and resource efficiency [1].

PT XYZ is a company engaged in gold jewelry manufacturing. One of its products is the Morena 12K bracelet, which passes through several production processes, including casting, stamping, filing, polishing, CNC machining, and grinding. During these processes, material loss may occur due to metal residues, machining chips, polishing dust, and other production waste. Although the amount of material loss at each process is relatively small, the accumulated loss can significantly affect production costs.

Production data collected from October 2025 to March 2026 show that the percentage of material loss fluctuated between 10.39% and 23.06%. This condition indicates that the production process has not yet achieved optimal material utilization. In addition, several production activities still experience delays and waste, which increase lead time and reduce overall production efficiency. Therefore, improvements are needed to minimize material loss and optimize the production process.

One method that can be used to evaluate material efficiency is Material Flow Cost Accounting (MFCA). MFCA is a management accounting method that identifies material flow and classifies production costs into positive costs (valuable products) and negative costs (material losses). By using MFCA, companies can identify hidden costs caused by material loss and determine production processes that require improvement [2]

However, MFCA mainly focuses on material flow and production costs. It does not identify waste related to production activities and process flow. Therefore, this study combines MFCA with Value Stream Mapping (VSM), a Lean Manufacturing tool used to visualize the production process and identify value-added and non-value-added activities. VSM helps companies recognize production waste and determine opportunities to improve process efficiency [3].

To identify the causes of waste, this study uses a Fishbone Diagram, which classifies the root causes into five factors: man, machine, material, method, and environment. Based on the identified causes, improvement alternatives are developed using the 5W+1H approach. The proposed improvements are then evaluated using Future State Value Stream Mapping (FSVSM) to estimate the potential improvement in production performance [4].

This study aims to identify material loss using Material Flow Cost Accounting (MFCA), analyze production waste using Value Stream Mapping (VSM), and develop improvement recommendations using Fishbone Diagram and 5W+1H to improve production efficiency. The results are expected to help PT XYZ reduce material loss, improve production efficiency, and support continuous improvement in gold jewelry manufacturing.

2. Method

This study was conducted at PT XYZ, a large-scale manufacturing company engaged in gold jewelry production in Indonesia. The company manufactures various jewelry products, including rings, bracelets, and pendants, using a multi-stage production process involving casting, stamping, filing, polishing, CNC machining, and grinding. The Morena 12K bracelet production line was selected as the research object because it experiences relatively high material loss and involves complex production activities, making it suitable for evaluating the integration of Material Flow Cost Accounting (MFCA) and Value Stream Mapping (VSM).

(1) Material Flow Cost Accounting (MFCA)

MFCA was first applied to quantify material flow throughout the production process and classify production costs into positive costs and negative costs. The analysis identified production processes with the highest material loss and quantified the hidden costs associated with inefficient material utilization. The MFCA results were then used as the basis for selecting critical processes requiring further analysis.[5], [6], [7].

(2) Value Stream Mapping (VSM)

Following the MFCA analysis, Value Stream Mapping (VSM) was employed to analyze the production process from both the current and future perspectives. Initially, the Current State Value Stream Mapping (CSVSM) was developed to visualize the existing flow of materials and information, identify Value-Added (VA), Necessary Non-Value-Added (NNVA), and Non-Value-Added (NVA) activities, and determine production waste and process bottlenecks contributing to material loss. The results of the CSVSM were then analyzed using a Fishbone Diagram to identify the root causes of the dominant waste. Based on these findings, improvement strategies were formulated using the 5W+1H approach. Subsequently, the proposed improvements were incorporated into the Future State Value Stream Mapping (FSVSM) to evaluate the expected production performance after implementation. The FSVSM was used to estimate improvements in production flow, lead time, and Process Cycle Efficiency (PCE), thereby providing the basis for evaluating the effectiveness of the proposed improvements before conducting the Future MFCA analysis. [8], [9], [10].

(3) Fishbone Diagram

The waste identified through CSVSM was further analyzed using the Fishbone Diagram to determine its root causes. The analysis classified the causes into five categories: man, machine, method, material, and environment, thereby providing a comprehensive understanding of the factors contributing to material loss.

(4) 5W+1H

Based on the identified root causes, improvement strategies were formulated using the 5W+1H approach (What, Why, Where, When, Who, and How). This method ensured that each corrective action was clearly defined, practical, and feasible for implementation within the production system.[11], [12]. [13].

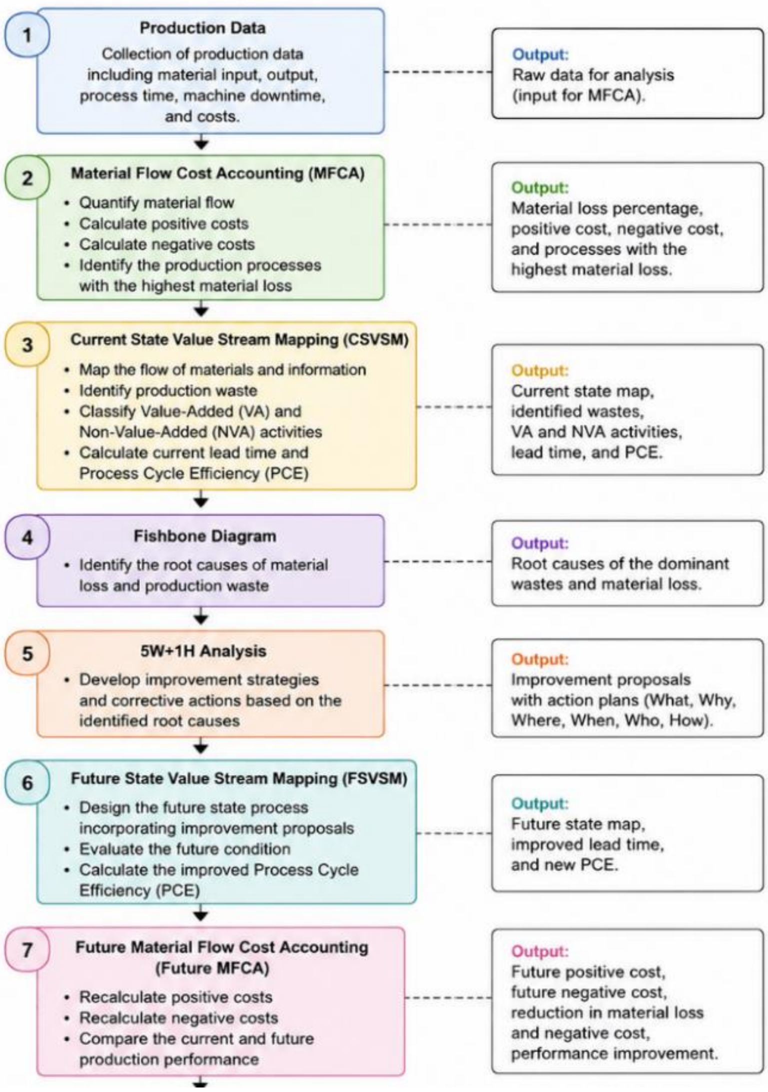

Figure 1. Research Method

3. Results and Discussion

(1) MFCA Analysis

Before analyzing the material losses in each production process, the Material Flow Cost Accounting (MFCA) method was applied to evaluate material utilization and allocate production costs into positive and negative costs. This analysis provides a quantitative assessment of the economic impact of material losses and identifies the production processes that contribute most significantly to hidden production costs. The average MFCA results for the Morena 12K bracelet production process during the period of December 2025 to February 2026 are presented in Table 1.

Table 1. Positive Cost vs Negative Cost Des 25-Feb 26

		Des 25 - Feb 26		
Averagel *Cost*	**Rp 13.122.977.544**		**Average *Input (gr)***	**10633,33**
Process	***Positive Output (gr)***	***loss (gr)***	***Positive Cost***	***Negative Cost***
Casting	10530,13	103,21	IDR 12.995.606.500	IDR 127.371.044
Stamping	10428,69	101,44	IDR 12.996.559.801	IDR 126.417.743
Filing	10324,40	104,29	IDR 12.991.748.020	IDR 131.229.524
Polishing	10221,18	103,22	IDR 12.991.774.037	IDR 131.203.507
CNC	9377,88	843,30	IDR 12.040.268.226	IDR 1.082.709.318
Grinding	8623,64	754,24	IDR 12.067.523.824	IDR 1.055.453.719

Table 1 presents the average MFCA results for the Morena 12K bracelet production process during December 2025–February 2026. The average total production cost was IDR 13,122,977,544, with an average material input of 10,633.33 g. The casting, stamping, filing, and polishing processes showed relatively low material losses (101.44–104.29 g), resulting in negative costs ranging from IDR 126.42 million to IDR 131.23 million, indicating relatively efficient material utilization.

In contrast, the CNC and grinding (slep) processes generated the highest material losses, amounting to 843.30 g and 754.24 g, with corresponding negative costs of IDR 1.083 billion and IDR 1.055 billion, respectively. These findings indicate that both processes contribute the largest hidden production costs and should be prioritized for improvement. The MFCA results provide a quantitative assessment of material loss and its economic impact, which serves as the basis for the subsequent VSM analysis to identify the root causes of waste and develop improvement strategies.

(2) VSM Analysis

Table 2 presents the time study results for each production activity, including cycle time (C/T), performance rating (PR), allowance, normal time (NT), and standard time (ST). These data provide the basis for evaluating process performance and identifying activities with improvement potential to enhance overall production and material loss efficiency.

Table 2. Standardization Cycle Time

No	Activity	C/T (Minute)	PR	Allowance Proportion	WN (Minute)	C/T (Minute)
1	A1	5,300	0,06	0,636	5,512	6,148
2	A2	10,933	-	0,000	0,000	10,933
3	A3	3,000	0,12	0,450	3,000	3,450
4	A4	9,967	0,00	0,897	11,661	12,558
5	A5	5,467	0,11	0,875	5,576	6,451
6	B1	38,100	0,06	4,572	40,767	45,339
7	B2	2,000	0,06	0,240	2,000	2,240
8	B3	6,500	0	0,000	0,000	6,500
9	B4	8,533	0,00	0,768	8,533	9,301
10	B5	2,467	0,05	0,296	2,467	2,763
11	C1	17,967	0,12	3,054	19,224	22,279
12	C2	13,667	0,12	2,323	13,667	15,990

No	Activity	C/T (Minute)	PR	Allowance Proportion	WN (Minute)	C/T (Minute)
13	C3	3,433	0,05	0,378	3,845	4,223
14	D1	3,600	0,05	0,396	3,600	3,996
15	D2	2,000	0,05	0,220	2,220	2,440
16	D3	17,800	0,13	3,026	20,292	23,318
17	D4	4,133	0,05	0,455	5,001	5,456
18	E1	75,600	0,08	9,072	75,600	84,672
19	E2	3,567	0,06	0,428	3,923	4,351
20	E3	52,300	0	0,000	0,000	52,300

The standard time obtained from the time study was used as the primary input for developing the Current State Value Stream Mapping (CSVSM). In addition to time data, information on material flow, waiting time, inventory, and production processes was incorporated to provide a comprehensive representation of the existing production system and to identify opportunities for process improvement.

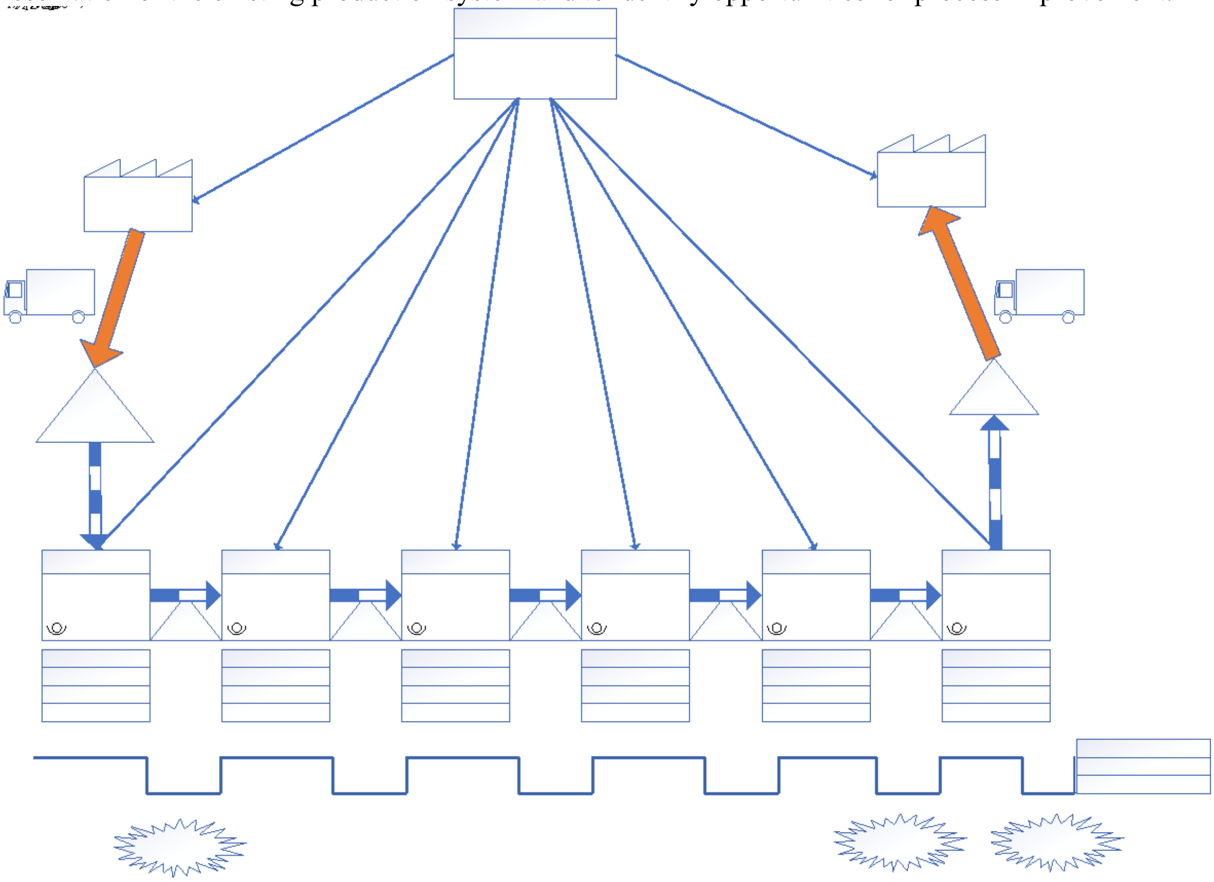

Figure 2. Current State Value Stream Map (CVSM)

Based on the Current State Value Stream Mapping (CSVSM), the next step was to identify production waste using Kaizen Burst. This technique highlights process areas with significant improvement potential by identifying activities that contribute to waste, increased lead time, and material loss. The identified Kaizen Bursts serve as the basis for developing improvement proposals to enhance production efficiency.

Table 3. Kaizen Burst Identification

Num	Kaizen Burst	Waste	MFCA Impact	Main Problem
1	Casting machine downtime	Waiting	Negative system cost	Downtime of the casting machine interrupts the production process, resulting in longer waiting times and increased system costs due to reduced production effectiveness.
2	Waiting for machining process	Waiting	Negative energy, system cost	Waiting during the machining process increases production lead time because machine operating parameters have not been standardized. This condition leads to higher energy consumption and increased system costs.
3	CNC program setup	Waiting, Defect	Negative material, energy, system cost	The lengthy CNC program setup extends production preparation time, resulting in higher energy consumption and system costs. In addition, incorrect program settings may cause rework, leading to increased material loss.
4	Cutting tool replacement	Waiting	Negative energy, system cost	Inefficient cutting tool replacement prolongs machine setup time, increasing machine idle time, energy consumption, and system costs.
5	Finishing detail	Defect	Negative material, energy, system cost	The finishing process generates gold dust as material loss and may produce defects when operators experience fatigue or lack of concentration. This condition increases material loss, energy consumption, and system costs.

The Kaizen Burst analysis identified the production activities with the greatest improvement potential. To determine the underlying causes of these problems, a Fishbone Diagram (Ishikawa Diagram) was employed. This tool systematically categorizes the root causes into five factors: Man, Machine, Material, Method, and Environment, providing a comprehensive understanding of the factors contributing to waste and material loss. The identified root causes were supported by quantitative evidence obtained from MFCA, including material loss and negative cost analysis, as well as operational evidence from CSVSM, such as waiting time, bottlenecks, and non-value-added activities. This triangulation of qualitative and quantitative data enhanced the reliability of the Fishbone Diagram.

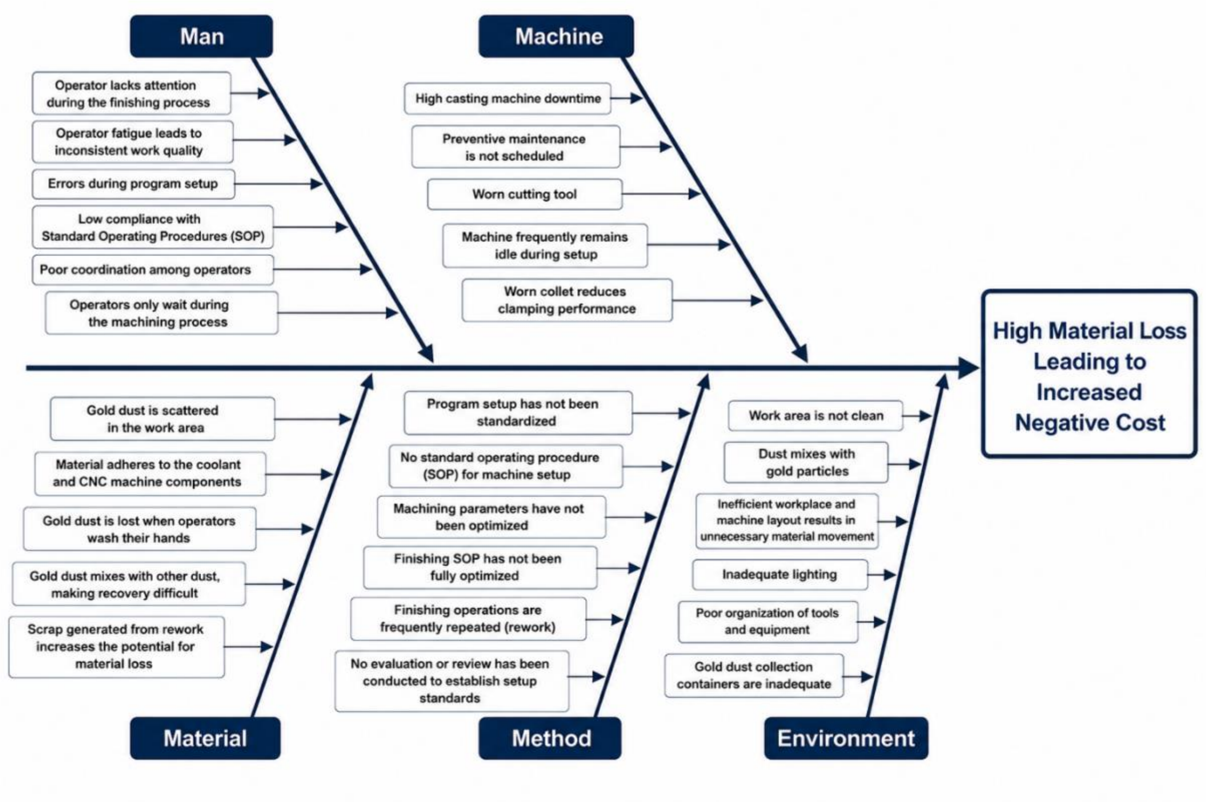

Figure 3. Fishbone Diagram

5W+1H

Table 4. 5W+1H

Faktor	What	Why	Where	When	Who	How
Man	Improve operator competence and work discipline	Operator accuracy is still inadequate, setup errors frequently occur, and compliance with Standard Operating Procedures (SOPs) is not optimal, leading to increased material loss.	CNC and Grinding areas	Before production and evaluated monthly	Production supervisor and operators	Conduct regular training, refresher training, pre-production briefings, operator performance evaluations, and strengthen supervision of SOP implementation.
Machine	Implement a preventive maintenance program	The absence of a preventive maintenance schedule results in frequent machine downtime and declining machine performance.	Casting and CNC machines	Weekly or monthly according to the maintenance schedule	Maintenance department	Establish a preventive maintenance schedule, perform routine inspections, and replace worn tools and machine components.
Method	Standardize setup and finishing procedures	The lack of standardized procedures causes inconsistent setup times among operators and non-uniform finishing quality.	CNC and Grinding areas	Before production implementation.	Production supervisor	Develop Standard Operating Procedures (SOPs), establish standard setup times, and provide training to all operators.
Material	Minimize gold material loss during production	Gold dust is scattered, adheres to machine components and coolant, and excessive rework generates additional scrap.	CNC and Grinding areas	After each production process.	Production operators and material recovery personnel	Provide dedicated recovery containers, collect gold dust regularly, and implement standardized material recovery procedures.
Environment	Improve workplace conditions	The work area is not sufficiently clean, the layout is inefficient, lighting is inadequate, and gold dust collection facilities are not optimized.	Entire production area	Daily, before and after production..	Production supervisor, operators, and the HSE/Housekeeping department	Implement the 5S program, improve workplace layout, enhance lighting conditions, and provide more effective and accessible gold dust collection containers.

The improvement proposals developed using the 5W+1H approach were incorporated into the Future State Value Stream Mapping (FSVSM) to evaluate their potential impact on production performance. The proposed improvements were not physically implemented during the study; therefore, the FSVSM represents an estimated future production scenario. The future-state model was developed under the assumption that all recommended actions, including machine maintenance, work standardization, production scheduling improvements, and operator training, were fully implemented. Based on these assumptions, process times, waiting times, and material losses were recalculated to estimate future production performance. Subsequently, Process Cycle Efficiency (PCE) and Future Material Flow Cost Accounting (Future MFCA) were evaluated to estimate the potential reductions in lead time, material loss, and negative costs. These estimated results provide an indication of the potential improvements that could be achieved if the proposed strategies were implemented at PT XYZ.

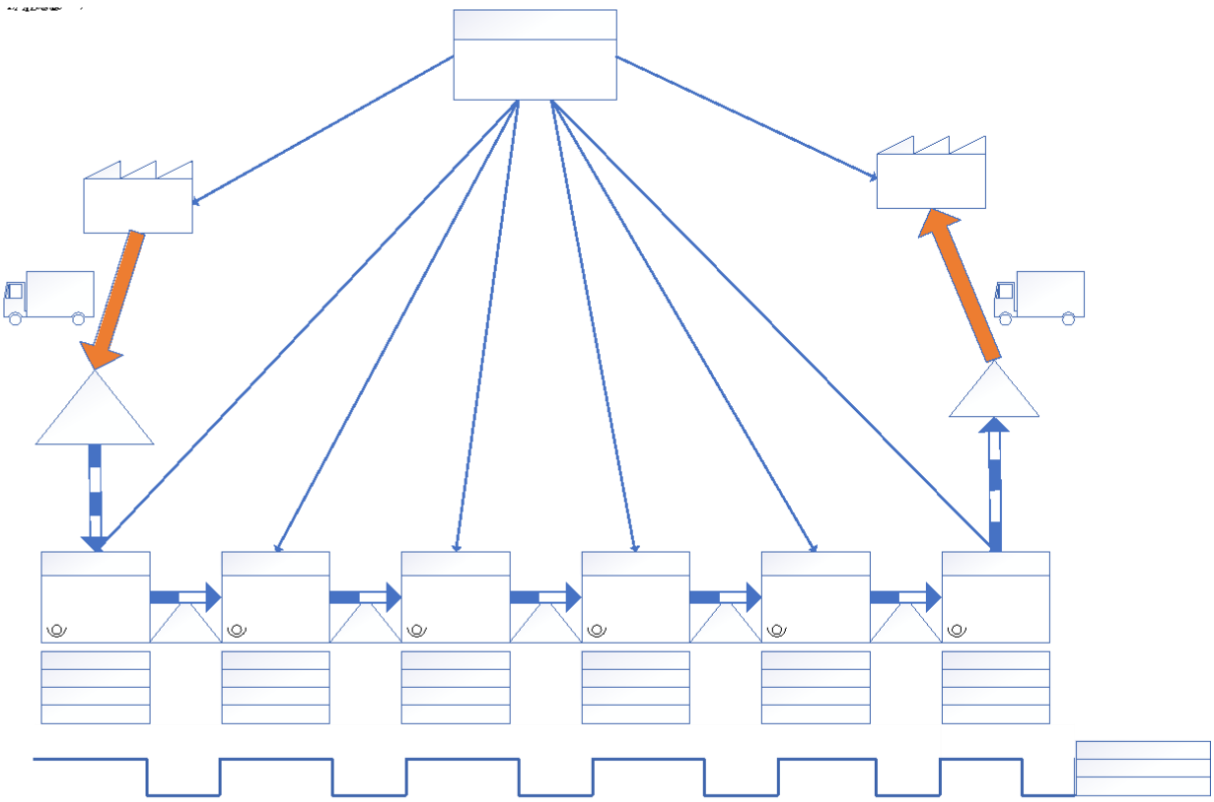

Figure 4. Future State Value Stream Mapping

The Future State Value Stream Mapping (FSVSM) was subsequently evaluated using Process Cycle Efficiency (PCE) to determine the effectiveness of the proposed improvement strategies. PCE represents the ratio of value-added time to the total production lead time and serves as an important performance indicator in Lean Manufacturing. An increase in PCE indicates that a greater proportion of production time is devoted to value-added activities, reflecting improved process efficiency and reduced production waste. the projected lead time was recalculated, and the future-state PCE was determined using the following equation:

Table 5. Process Cycle Efficiency

C/T	VA	PCE	C/T	VA	PCE
421,42	148,70	35,29%	301,817	128,9	42,71%

$$\Delta PCE = PCE\ FSVSM - PCE\ CSVSM$$
$$\Delta PCE = 42{,}71\% - 35{,}29\%$$
$$\Delta PCE = 7{,}42\%$$

Based on the estimated future-state conditions, the total lead time decreased from 421.417 minutes to 381.967 minutes, resulting in an increase in the projected PCE from 35.29% to 42.71%. Therefore, the reported PCE represents the expected performance improvement under the proposed improvement scenario rather than the results of actual implementation at PT XYZ.

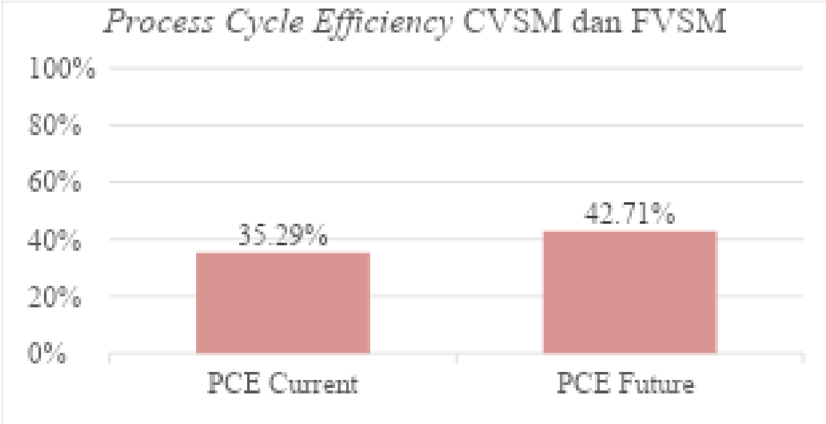

Figure 5. Process Cycle Efficiency

The future-state Process Cycle Efficiency (PCE) was estimated rather than obtained through actual implementation. The projected PCE was developed based on the assumption that all proposed improvement actions, including machine maintenance, work standardization, production scheduling improvements, and operator training, were successfully implemented. The future-state production process was modeled by reducing non-value-added (NVA) and waiting times identified in the Current State Value Stream Mapping (CSVSM), while the value-added (VA) activities were assumed to remain unchanged.

Following the evaluation of the projected Process Cycle Efficiency (PCE), the effectiveness of the proposed improvements was further assessed using Future Material Flow Cost Accounting (Future MFCA). While PCE measures the operational improvement achieved through reduced lead time, Future MFCA evaluates the corresponding economic impact by recalculating material flow, positive costs, and negative costs under the proposed future-state conditions. This analysis provides an estimate of the potential reduction in material loss and hidden production costs resulting from the implementation of the proposed improvement strategies.

Table 6. Positive Cost vs Negative Cost Apr-Jun 26

		Apr - Jun 26		
Average Total Cost	Rp 13.589.734.004		*Average (gr)*	8790,0
Process	*Positive Output (gr)*	*loss (gr)*	*Positive Cost*	*Negative Cost*
Casting	8653,27	136,73	IDR 13.378.338.141	IDR 211.395.862
Stamping	8563,79	89,47	IDR 13.449.218.422	IDR 140.515.582
Kikir	8426,91	136,89	IDR 13.372.510.944	IDR 217.223.059
Poles	8279,12	147,78	IDR 13.351.409.756	IDR 238.324.248
CNC	8018,67	260,46	IDR 13.162.208.446	IDR 427.525.558
Slep	7821,97	196,69	IDR 13.256.385.557	IDR 333.348.447

Table 6 presents the average Future MFCA results for the Morena 12K bracelet production process during April–June 2026. The results indicate that the proposed improvements reduced material losses and negative costs across all production processes. Although the CNC and grinding (slep) processes remained the largest contributors to material loss, their negative costs decreased significantly to IDR 427.53 million and IDR 333.35 million, respectively. These findings demonstrate that the proposed improvements have the potential to improve material utilization, reduce hidden production costs, and enhance overall production efficiency.

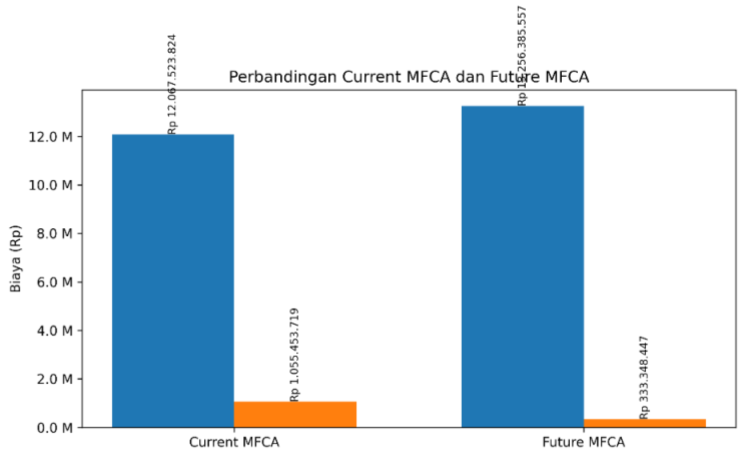

Figure 6. Current MFCA vs Future MFCA

Figure 6 shows that the proposed improvements increased the positive cost from IDR 12.07 billion to IDR 13.26 billion, while the negative cost decreased significantly from IDR 1.06 billion to IDR 333.35 million. This indicates a substantial reduction in material loss and hidden production costs, demonstrating that the proposed improvements have the potential to enhance material utilization and overall production efficiency.

4. Conclusion

This study has several limitations. First, the proposed improvements, Future State Value Stream Mapping (FSVSM), and Future Material Flow Cost Accounting (Future MFCA) were evaluated based on estimated performance rather than actual implementation at PT XYZ. Therefore, the reported improvements in Process Cycle Efficiency (PCE), material loss, and production costs represent projected outcomes under the proposed improvement scenario. Second, the study was limited to the Morena 12K bracelet production process using production data collected over a six-month period, which may limit the generalizability of the findings to other products or manufacturing environments.

Future research should validate the proposed improvements through actual implementation in an industrial setting and compare the projected results with actual production performance. Furthermore, the integrated MFCA–VSM framework can be extended by applying it to different products or manufacturing industries and by incorporating complementary methods, such as Failure Mode and Effects Analysis (FMEA), simulation, or Life Cycle Assessment (LCA), to provide a more comprehensive evaluation of production efficiency, cost reduction, and environmental performance.

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How to cite this article:
Pratama A D, Lukmandono, Basuki HM G. Reducing Material Loss in Gold Bracelet Production Using Material Flow Cost Accounting and Value Stream Mapping. Jurnal Teknologi dan Manajemen. 2026 July 7(2): 142-153
DOI: 10.31284/j.jtm.2026.v7i2.9242