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# LEAD-TIME IMPROVEMENT OF KAM CUTTER PROCESSING USING THE POKA-YOKE METHOD AT A MANUFACTURING COMPANY IN CIKARANG

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**ABSTRACT**

The KAM Cutter is a cutting blade used to manufacture plastic pellets through underwater pelletizing. A manufacturing company in Cikarang reported that, on average, an order completion rate for KAM Cutter for 2023-2024 was 12,51%, which is highly below expectations. This research will improve production capacity by enhancing lead time on the production floor. Lean Manufacturing tools used in the research involve Value Stream Mapping, Fishbone Diagram, Poka-Yoke, and Fixture Design. The findings of this research have revealed that by using a new fixture design, the CNC Milling process can reduce the lead time from 15,24 minutes to 2,09 minutes per unit and reduce the Surface Grinding process from 14,88 minutes to 0,87 minutes per unit while maintaining an overall lead time reduction of 84,38%, from 32 minutes to 5 minutes per unit. The above improvements increased production capacity from 6.507 units/year to 49.518 units/year, approaching the target of 54.000 units/year while boosting the company's revenue from IDR 2,47 billion to IDR 18,81 billion per year. Besides, the Non-Value-Added process time was reduced by 68,72%, reflecting significant efficiency improvements in the production process.



## Introduction

Global plastic resin production continues to grow annually, reaching over 368 million metric tons in 2019, driven by the automotive, construction, and packaging sectors [1]. Meanwhile, Indonesia's plastic industry has experienced significant growth in recent years, with production estimated at 7.04 million tons and projected to rise to 8.88 million tons by 2029, representing a compound annual growth rate (CAGR) of over 4,5% [2]. This growth drives the increasing demand for cutting tools each year, exemplified by a specific component called the KAM Cutter.

The KAM Cutter is a cutting blade that produces plastic pellets via underwater pelletizing, as illustrated in Figure 1. In this process, molten plastic flows through the sprue (e) and is distributed through the die-face (d), where it is cut by the KAM Cutter Blade (c) to produce granulate (b) that is cooled by water. The water-carried granulate is then separated in a hopper. Each KAM Cutter Blade holder can contain various blades, ranging from 6, 12, 18, 20, 24, 32, to 40 pieces. The KAM Cutter Blade is a consumable item frequently replaced due to the base material design, which uses S45C for the holder and Nitro for the cutting edge (Figure 2). After heat treatment, the cutting edge hardness ranges between 52–54 HRC, which is softer than the die-face's hardness of 58–60 HRC. Additionally, automatic regrinding occurs every hour during production, necessitating blade replacement every 1–2 months.

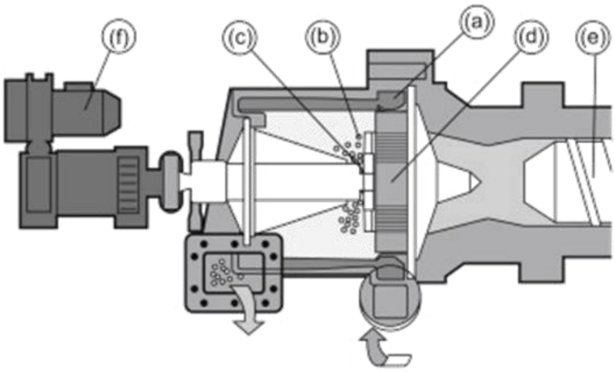


Figure 1. Under Water Pelletizing

Source: Internal Company, (2024)

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Figure 2. Various Types of KAM Cutters

Source: Internal Company, (2024)

At one foreign-invested manufacturing company in Indonesia, the average weekly demand is 1,000 pieces from its European headquarters. However, the company can only supply 125 pieces per week, as shown in Figure 3. The calculated lead time to produce 125 pieces per week over five working days with two shifts per day (8 hours per shift) is 38.4 minutes per product. Using the same working hours, meeting the market demand of 1.000 pieces per week would require a lead time of 4.8 minutes per product, leaving a gap of 33,6 minutes per product that the company must address.

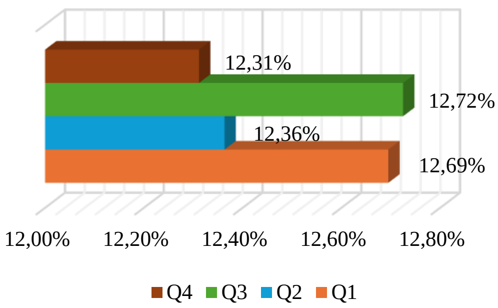


Figure 3. Order Fulfillment July 2023-June 2024

Source: Internal Company, (2024)

Research conducted by Pötters highlights that various optimization methods for production floor assembly processes in manufacturing industries indicate that Poka-Yoke significantly reduces lead time, decreasing it from 4.48 minutes to 1,32 minutes—a reduction of 3,26 minutes [3]. Similarly, research by Hernadewita demonstrates that applying the Poka-Yoke method to the B8A rotor component in an automotive spare parts manufacturing company eliminated dimensional defects in materials entering production, achieving zero defects the following month. Additionally, Poka-Yoke implementation improved production cycle time to 79,77 seconds per unit [4].

This research aims to identify the root causes of high lead times in the production process of the KAM Cutter, develop a design solution to reduce these lead times and evaluate the resulting improvement in production capacity after implementing the proposed solution. By addressing inefficiencies and optimizing production processes, this study seeks to close the gap between the current production output and market demand, ultimately enhancing the company's ability to meet customer expectations effectively.

## Methods

This study employs data collection methods comprising literature reviews and field research. The literature review incorporates theories related to Value Stream Mapping, Fishbone Diagram, Poka-Yoke, Fixtures, and several relevant journals, while the field research involves interviews, direct observations, and documentation [5][6][7].The data processing methodology in this engineering practice includes the following steps (as illustrated in Figure 3):

1. Calculating Productivity
   Productivity calculation determines the average machine productivity before and after implementing improvements [8][9]. The productivity of each machine and the overall average is calculated using Equations 1 and 2[10][11]:

$$P_m = \frac{Q_p}{t_m} \quad (1)$$

   Explanation:
   $P_m$ : Machine Productivity Index
   $Q_p$ : Quantity of products processed *(pcs)*
   $t_m$ : Product processing time *(minutes)*

$$P_t = \frac{\sum P_m}{\sum Q_m} \quad (2)$$

   Explanation:
   $P_t$ : Total Machine Productivity Index
   $\sum P_m$: Sum of Machine Productivity Indices
   $\sum Q_m$: Number of machines used *(pcs)*
2. Developing Value Stream Mapping
   To facilitate analysis, value stream mapping is created following these steps [12][13]:
   a. Create a Current State Mapping to identify improvement areas and potential solutions[14].
   b. Identify waste-causing bottlenecks that result in high lead times[15].
   c. Develop a Future State Mapping based on improvements, serving as a foundation for ongoing enhancement[16].
   d. Compare the Current State Mapping and Future State Mapping plots[17].

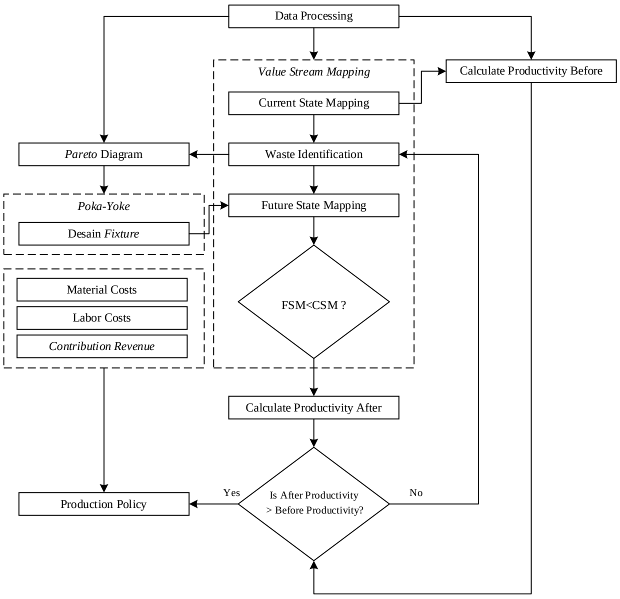


Figure 4. Flow Process of Research

3. Creating Pareto Diagram
   A Pareto diagram is created to identify machining processes contributing the most to high lead times [18][19].
4. Designing Poka-Yoke
   The Poka-Yoke stage involves designing fixtures to reduce lead times based on the Pareto diagram findings using CAD/CAM (Computer-Aided Design/Computer Aided Manufacturing) software [20][21]. Variables in the fixture design include machine table dimensions, the number of machines used, available operators, and permitted working hours[22][23][24].
5. Calculating Benefit/Cost Ratio
   The cost-benefit analysis includes calculating material and labour costs alongside the revenue increase resulting from fixture implementation [25].

## Results and Discussions

Two main processes are required to produce a KAM cutter: machining the cutter body and cutting edge. The body machining involves several stages, including material cutting, body profiling, deburring, welding to attach the body to the cutting edge, finishing, and quality control (QC) inspection before packing. Meanwhile, cutting-edge manufacturing is outsourced to a third party and includes material treatment to achieve a 52–54 HRC hardness, followed by cutting using a wire-cut machine. The results of the current state mapping based on these processes are shown in Figure 5.

The calculation of the individual and overall Machine Productivity Index at the beginning of the study is presented in Table 1. This data serves as a baseline for comparison with the productivity data after improvements are implemented. Based on the initial data, it is evident that the lowest machine productivity values are below 1, specifically for the CNC Milling and Surface Grinding machines, with respective values of 0,066 pcs/min and 0,067 pcs/min. The overall Machine Productivity Index was calculated to be 1,148 pcs/min.

Table 1. Current Productivity Index

| **Machine/ Process** | **Pm** *(pcs/ minutes)* | **Pt** *(pcs/ minutes)* |
|---|---|---|
| CNC Milling | 0,066 | 1,148 |
| SandBlasting | 2,884 | |
| Welding | 1,574 | |
| Surface Grinding | 0,067 | |

Waste identification was conducted using a Pareto diagram derived from the current state mapping. This study defines waste as the cycle time for each process. Based on the Pareto diagram in Figure 6, the processes with the most extended cycle times are CNC Milling and Surface Grinding, with 15,24 minutes (47,9%) and 14,88 minutes (46,8%), respectively. These two processes account for a cumulative percentage of 94,70%.

After identifying improvement areas from the Pareto diagram, a refinement mapping was developed using a fishbone diagram involving experts with over ten years of experience. The results of this activity are shown in Figures 7.

Based on the analysis of the fishbone diagrams in Figures 7, the primary causes of high lead times in the CNC Milling and Surface Grinding processes can be addressed by implementing a Poka-Yoke solution involving a more effective fixture design.

Factors such as operators' limited understanding of fixture usage, variability in skill levels, improper machine calibration, and inefficient fixture designs for the CNC Milling process contribute to process consistency. To resolve these issues, a Poka-Yoke approach can be applied by designing fixtures that only allow materials to be mounted in the correct orientation, thereby minimizing errors. Additionally, the fixture's capacity can be increased from 8 cavities to 20 cavities, significantly reducing lead time.

In the Surface Grinding process, issues such as machine vibrations affecting grinding results, fixture instability during operations, and a lack of standardized fixture settings can be resolved with a more stable and modular fixture design. Introducing fixtures capable of absorbing vibrations and equipped with reference points to maintain material positioning

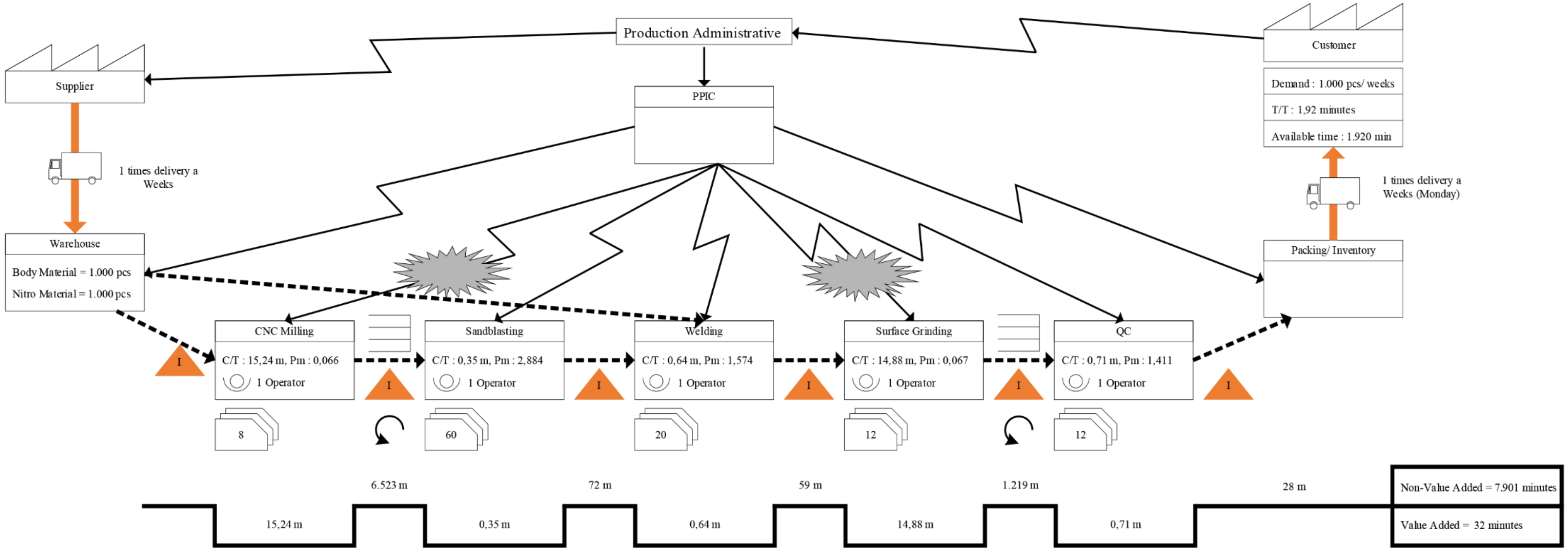


Figure 5. Current State Mapping

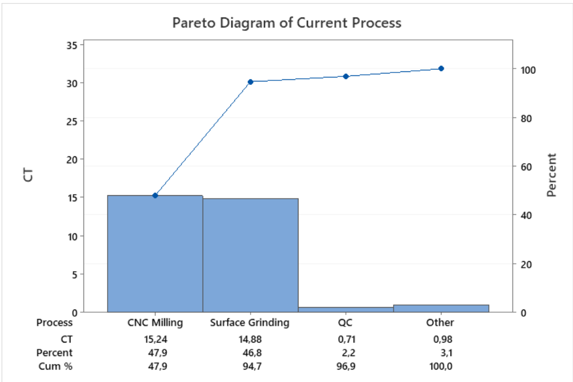


Figure 6. Pareto Diagram

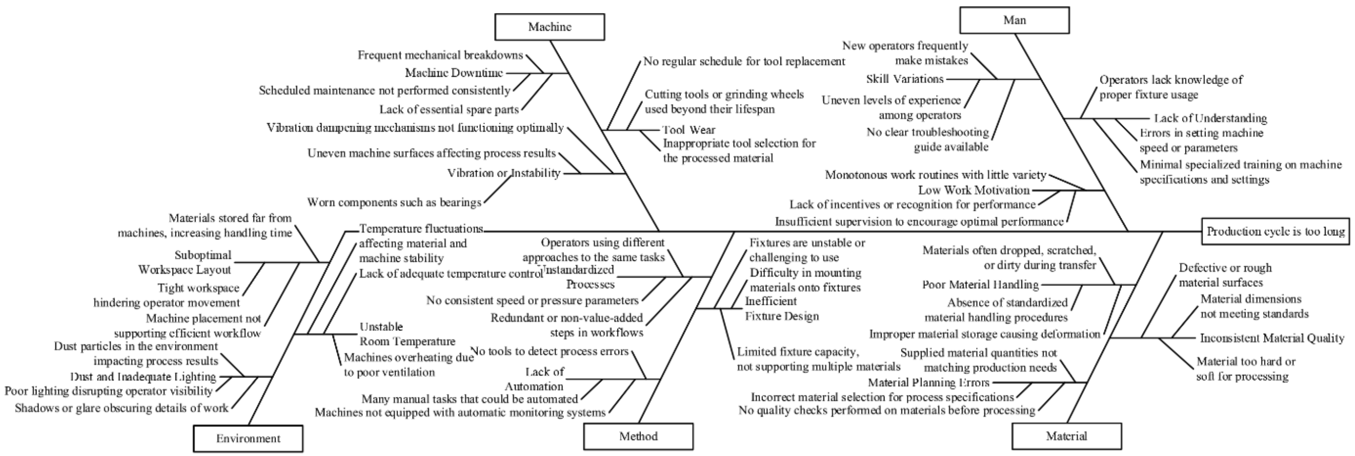


Figure 7. Fishbone Diagram

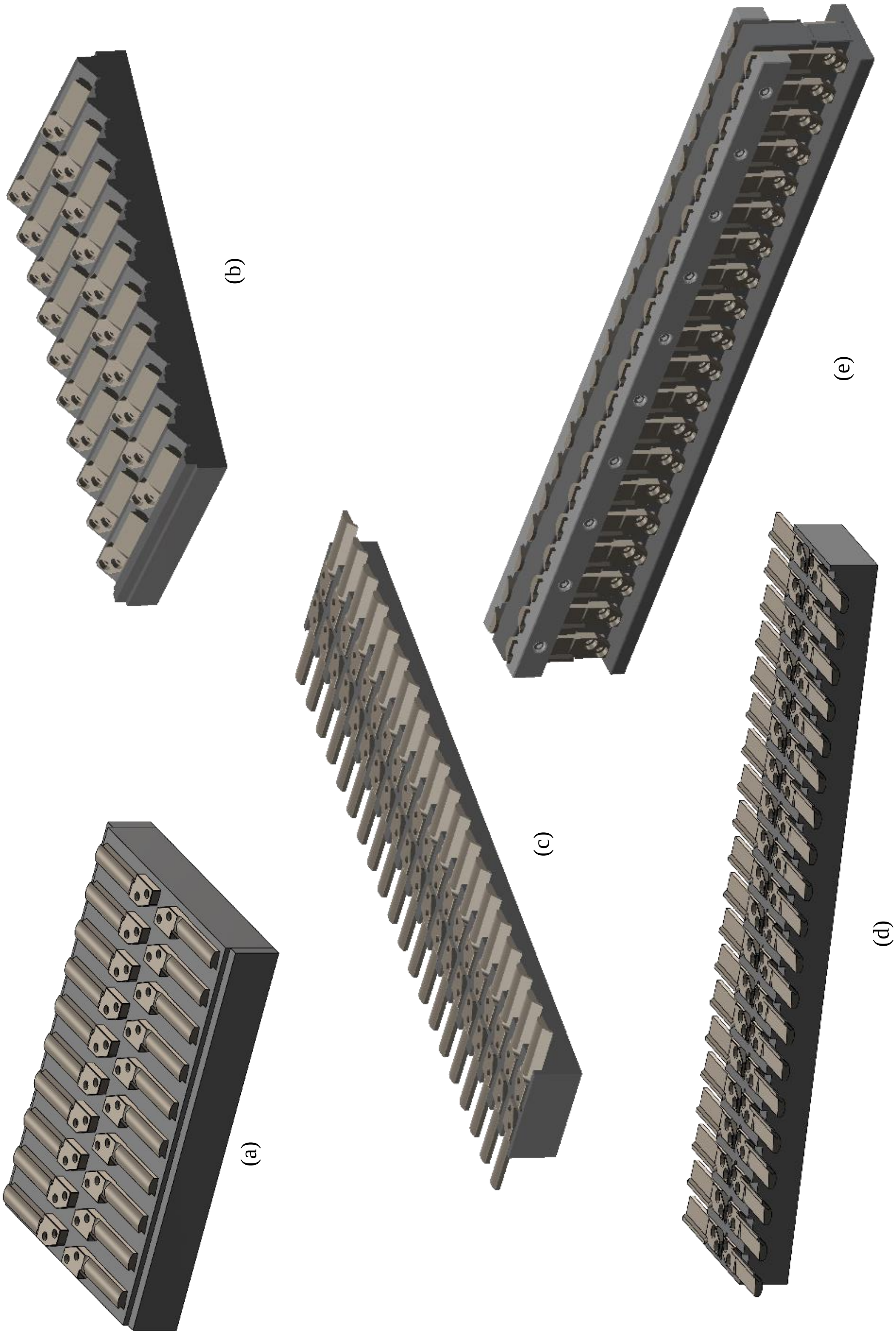


Figure 8. Fixture Design
(a) Fixture for CNC Milling OP1
(b) Fixture for CNC Milling OP2
(c) Fixture for Surface Grinding OP1
(d) Fixture for Surface Grinding OP2 & OP3
(e) Fixture for Surface Grinding OP4

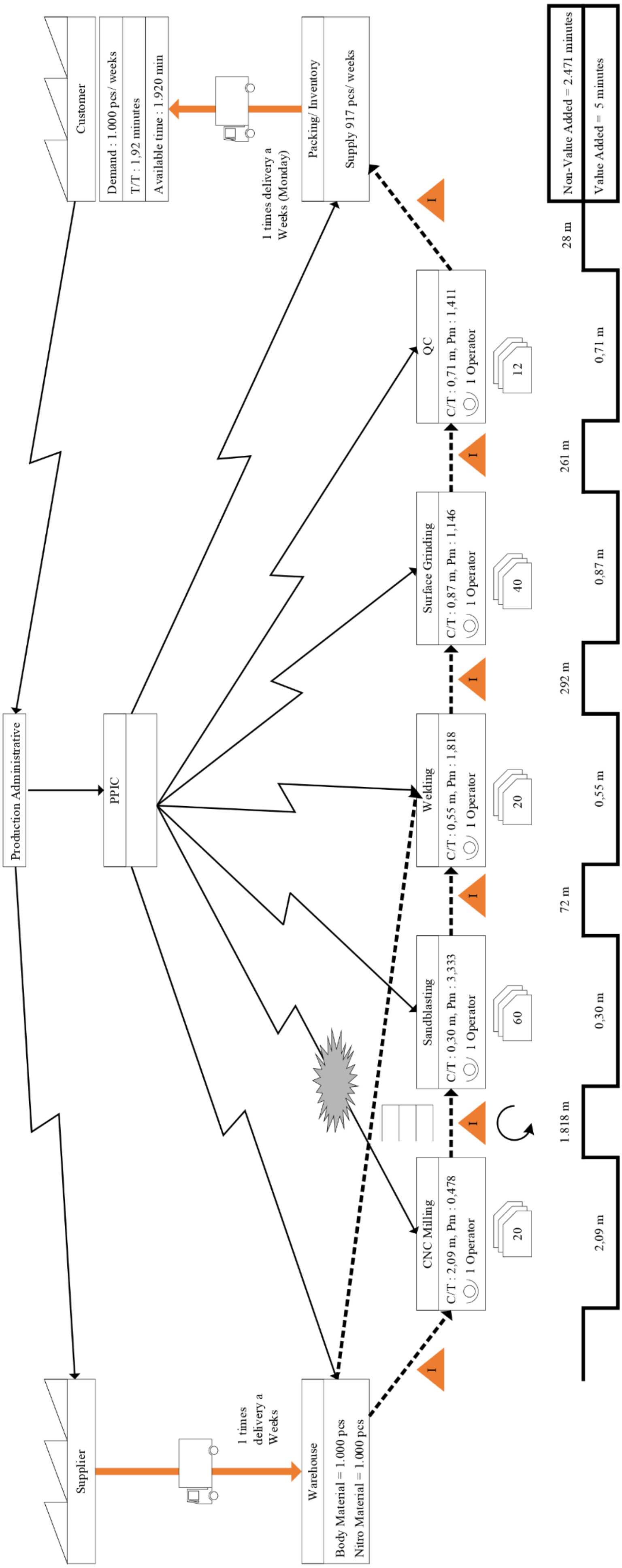


Figure 9. Future State Mapping

enhances the quality of grinding results. Furthermore, increasing fixture capacity from 12 cavities to 40 cavities allows for significant improvements in process efficiency. To ensure the sustainability of these improvements, operator training on the usage of new fixtures and the implementation of standardized visual guidelines should be conducted. This ensures consistent adoption and optimizes the benefits of the redesigned fixtures.

The implementation results of the proposed solution are illustrated in Figure 8. The material ordering model was modified to use materials with pre-levelled surfaces, eliminating the need for planar processing. The CNC Milling process was divided into two operations, OP1 and OP2, with the quantity of KAM Cutters on the fixture increasing from 2 pieces per cycle to 20 pieces per cycle. This adjustment significantly reduced the lead time in the previous process (Figures 8a and 8b). In this new process, the cycle time decreased from 15,24 minutes per piece to 2,09 minutes per piece. Furthermore, by increasing the fixture capacity on the Surface Grinding machine from 12 pieces per cycle to 40 pieces per cycle across four operational steps, the cycle time was reduced from 14,88 minutes per piece to 0,87 minutes per piece (Figures 8c, 8d, and 8e).

The future state mapping process was conducted to assess the extent of improvements made objectively and to serve as a reference for future enhancements (Figure 9). As shown in Figure 9, Non-Value-Added (NVA) processes decreased significantly, from 7,901 minutes to 2.471 minutes—a reduction of 5.430 minutes or 68,71%. Similarly, Value-Added (VA) processes also declined, from 32 minutes to 5 minutes, representing a reduction of 27 minutes or 85.78%.

The calculation of the Machine Productivity Index, both individual (*Pm*) and overall (*Pt*), after the improvements can be seen in Table 2. The table indicates that the lowest individual Machine Productivity Index (Pm) was for CNC Milling, which still showed improvement from 0,066 to 0,487. The overall Machine Productivity Index (Pt) improved from 1,148 to 1,694. This indicates that the process improvements implemented were practical and resulted in better performance.

Table 2. Future Productivity Index

| Machine/ Process | Pm (pcs/ minutes) | Pt (/ minutes) |
|---|---|---|
| CNC Milling | 0,066 | 1,148 |
| SandBlasting | 2,884 | |
| Welding | 1,574 | |
| Surface Grinding | 0,067 | |

Table 3 shows the cost calculation required to produce fixtures that increase capacity and reduce process lead time. The total cost for producing five fixtures amounts to IDR 76.875.000. The resulting increase in production capacity significantly improved the company's annual revenue from IDR 2.472.660.000 to IDR 18.816.840.000. This increase was due to a rise in production from 6.507 pcs/year to 49.518 pcs/year, approaching the company's target of 54.000 pcs/year.

Table 3. Fixture Cost

*(thousand)*

| Name of Part | Dimension | Material | Cost |
|---|---|---|---|
| Fixture CNC Mill OP 1 | #380 x 250 x 50 | SNCM 439 *(Flame Hardened 48-50 HRC)* | 14.250 |
| Fixture CNC Mill OP 2 | #460 x 250 x 50 | | 16.875 |
| Fixture Surface Grinding OP 1 | #760 x 115 x 50 | | 13.125 |
| Fixture Surface Grinding OP 2 & 3 | #760 x 115 x 50 | | 13.125 |
| Fixture Surface Grinding OP 4 | #760 x 115 x 75 | | 19.500 |
| ***Total Cost*** | | | **76.875** |

Based on the significant achievements of this study, the company has implemented a new policy involving the reorganization of the CNC Milling process into two operations, OP1 and OP2, while maintaining four operations for Surface Grinding (OP1, OP2, OP3, and OP4). However, the number of cavities per process for surface grinding has been increased to 40 pcs per process, which aligns with the new fixture design. Additionally, the company has provided worker training for operators on using the improved fixture and will conduct evaluations every four months to ensure consistency in the achieved results. If production operators consistently perform their tasks effectively, the company plans to extend similar improvements to other products to achieve optimal productivity. Furthermore, the company will continuously enhance market penetration to increase sales and competitiveness.

Compared to the research by Pötters, which reduced lead time from 4.48 minutes to 1.32 minutes (a reduction of 70.54%), the lead time reduction achieved in this study is more substantial at 84.38%, from an initial lead time of 32 minutes to 5 minutes[3]. Unlike the study by Hernadewita, which successfully reduced defect rates to zero but increased the production cycle time by 79.77 seconds, this study maintained a zero defect rate from the beginning of the production process. It simultaneously reduced the production cycle time to 5 minutes—a significant improvement of 84.38%[4].

## Conclusions

This report is compelling enough to point out and resolve the main difficulty resulting in long lead times in the production of KAM Cutter at a manufacturer located in Cikarang. By adopting some of the techniques of Lean Manufacturing, including Value Stream Mapping, Fishbone Diagram, and Poka-Yoke, the company can improve its production process and create a much better fixture design. The improvement will result in a significant increase in production efficiency, the ability to cope with demand, and reduced non-value added. Additionally, the company conducts regular activities for constant improvement: operators' training and regular evaluation to support improvements and planning to apply similar methods to other products. Research has shown that appropriate methods in production management may have a relatively positive impact on company efficiency, capacity, and competitiveness.

## Author Contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, Singgih Juniawan and Saiful Hendra; methodology, Saiful Hendra; software, Singgih Juniawan; validation, Hasbullah, Daruki and Uti Roysen; formal analysis, Saiful Hendra; investigation, Singgih Juniawan; resources, Singgih Juniawan; data curation, Eka Irawanti; writing—original draft preparation, Singgih Juniawan; writing—review and editing, Daruki; visualization, Eka Irawanti; supervision, Sauful Hendra; project administration, Eka Irawanti; funding acquisition, Uti Roysen. All authors have read and agreed to the published version of the manuscript.” Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

## Conflicts of Interest

Declare conflicts of interest or state “The authors declare no conflict of interest.” Authors must identify and declare any personal circumstances or interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results. Any role of the funders in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; or in the decision to publish the results must be declared in this section. If there is no role, please state “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results”.

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