Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 10, Issue 2; April-June, 2023, pp. 74-81

http://www.krishisanskriti.org/Publication.html

Production Line Improvement using Value Stream Mapping: A Bearing Cage Manufacturing Case Application

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Abstract—*Lean manufacturing (LM) is a Japanese business strategy that aims to identify and eliminate waste. This paper presents value stream mapping (VSM), one of the most significant LM techniques, to redesign production systems in bearing cage manufacturing as a case study. To achieve this goal, the team formed by implementing lean fundamental principles to construct VSM to identify and eliminate waste. This includes selecting the product, designing the concept, formulating the time frame, and calculating times such as Uptime, throughput time, value added (VA) and non-value added (NVA) time, etc. The current and future state of the bearing cages production line is described in the paper. The future state map represents the proposed improvement action plans. The future VSM results showed that the production throughput time was reduced significantly by 12%.*

Keywords: *Lean manufacturing, value stream mapping, throughput time, waste.*

1. INTRODUCTION

Lean manufacturing is a production approach that aims to eliminate waste and improve efficiency. Value stream mapping (VSM) is a tool used in lean manufacturing that involves creating a visual representation of the entire production process to identify areas of waste and inefficiency [1]. To implement lean manufacturing through VSM, organizations should start by identifying the product or service being produced and the value it provides to the customer. Then, they should map out the current production process and analyze it to identify waste areas, such as overproduction, waiting, defects, excess inventory, unnecessary motion, overprocessing, and new talent [2]. Based on the analysis, a future state should be designed that eliminates waste and improves efficiency. This can involve changes to the production process, such as reducing setup times, improving material flow, and redesigning production lines [3]. The next step is to implement the changes and continuously monitor the production process to ensure the changes have the desired effect. Metrics such as throughput time, cycle time, waiting time, and quality should be used to measure performance and identify areas for improvement. Implementing lean manufacturing through VSM can lead to lower costs, higher quality, and improved competitiveness in the marketplace [4].

Rahani et al. [5] demonstrated using the VSM technique on the Front disc, D45T. They found a substantial gap between real Work and Standardized Work. They proposed improved SOP for continuous improvement. Domingo et al.[6] analyzed the internal flow of the material in the assembly line of the BOSCH plant in Spain. Using VSM, they developed a timetable and route for the milk run to enhance material flow. Lian and Landeghem [7] used simulation tools for building VSM models. By altering the sequence of processes and redesigning the process layout, they found a reduction in the lead times, lowering the WIP inventory, increasing value-added ratios, and solving the bottleneck problem. Stadnicka and Litwin [8] presented the integration of VSM with a system dynamics analysis (SDA), leading to increased possibilities for identifying the waste and its elimination. They developed the model using Vensim software, considering the inventory limitations and various disturbances. The integrated approach further helped identify the problems with WIP and production volume. Braglia and Frosolini [10] argue that acknowledging and addressing uncertainty in VSM analysis is essential because it can significantly impact the accuracy and effectiveness of the improvement efforts. Saraswat and Kumar [11] comprehensively reviewed the literature on value stream mapping (VSM) analysis and its use in waste reduction efforts. They introduce the concept of VSM and its role in lean manufacturing, which involves identifying and eliminating process waste. Sabaghi

And Rostamzadeh [12] describes a case study of a plastic fabrication company seeking to improve its production process by applying kanban and value stream mapping (VSM) analysis, which are fundamental principles of lean manufacturing. Singh and Kumar Garg [13] reviewed the literature on VSM, summarizing its history, guides, and practical applications. They also discuss the challenges and limitations of VSM and the benefits and success factors associated with its implementation. They also used simulation software to model the existing production process and compare it to a proposed approach incorporating Kanban and VSM principles. They evaluate the effectiveness of the proposed method based on several performance metrics, including lead time, inventory levels, and throughput.

Gangala, Modi, Machado, and Trojanowska [14] analyzed the production process of a deck roller assembly unit intending to reduce the cycle time. They have also used the Value Stream Mapping (VSM) technique to identify the non-value-added activities and inefficiencies in the production process. They collected data on the process flow, lead time, and cycle time of the assembly unit and mapped out the current state of the production process. They then analyzed the data and identified the areas where cycle time could be reduced.

The literature study highlighted that VSM is an effective tool to improve efficiency, but it has not been well explored in bearing cage manufacturing industries. Thus, the present study used VSM in the bearing cage manufacturing industry to reduce waste and improve production line efficiency.

The different time calculations commonly used in VSM are described in the below section:

a) Cycle Time: The cycle time is the time required to complete one cycle of a process. It can be calculated by dividing the total processing time by the number of units produced.
b) Lead Time: The lead time is the time required to complete a process from the beginning to the end, including waiting time. It can be calculated by adding up a single unit's processing time, waiting time, and transportation time.
c) Value Added time: Value-added time is spent on activities that directly add value to the product or service being produced. These activities transform the product into its final form and are activities customers are willing to pay for. Examples of value-added activities include assembly, manufacturing, processing, and testing.
d) Non-Value Added time: non-value-added time refers to the time spent on activities that do not add value to the product or service being produced. These activities include waiting, inspection, transportation, rework, and other activities that do not transform the product or service in any way.
e) Throughput time: Throughput time in VSM is the total time it takes to complete a product or service from start to finish, including all value-added and non-value-added activities.
f) Waiting time: on the other hand, refers to when a product or service is idle or waiting for the next process step to be completed.
g) Kaizen: Kaizen is a Japanese term that means "continuous improvement." It is a philosophy and methodology emphasizing minor, incremental improvements made over time to improve processes and outcomes significantly.

2. MATERIALS AND METHODS

Value Stream Mapping (VSM) is a lean management tool used to analyze, design, and optimize the flow of materials, information, and activities required to produce a product or service. The methodology of VSM can be broken down into several key steps:

Step 1 - Identify the Value Stream: The first step in VSM is to identify the value stream or the set of activities required to produce a product or service. This involves mapping out the entire process from start to finish, including all inputs, outputs, and actions required.

Step 2 - Define Value: Once the value stream has been identified, the next step is to define value from the customer's perspective. This involves identifying the specific features and characteristics the customer values and is willing to pay for.

Step 3 - Map the Current State: With the value stream and value defined, the next step is to map the current state of the process. This involves identifying all the activities, resources, and inputs required to produce the product or service and the time and cost associated with each move.

Step 4 - Analyze the Current State: Once the current state has been mapped, the next step is to identify areas of waste, inefficiency, and improvement opportunities. This involves identifying non-value-added activities, waiting times, bottlenecks, and other areas of waste that can be eliminated or optimized.

Step 5 - Design the Future State: With the current state analyzed, the next step is to design the future state or the ideal state of the process. This involves identifying ways to eliminate waste, optimize efficiency, and improve quality to create the best possible process.

Step 6 - Implement the Future State: The final step in VSM is to implement the future state and monitor the process to ensure that the improvements are sustained over time. This involves creating a plan for implementing the changes, training employees, and continuously monitoring the process to ensure it continues delivering value to the customer.

3. CASE STUDY

This section provides information regarding the case company, including its background, the selection of products for the case study, as well as the current and future state maps.

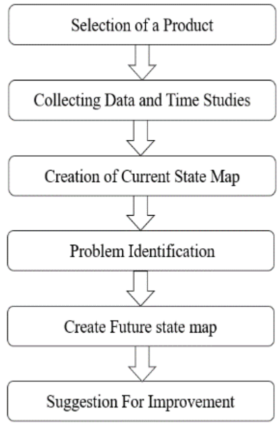


Figure 1: Methodology of VSM implementation

This study focuses on a manufacturer of bearing cages located in Gujarat, India. The company operates on a job shop system, producing products based on customer orders. After conducting a current state map analysis of the production lines for different products, it was discovered that the RHCRB production line was a bottleneck, leading to delays in orders and poor production control resulting in a high amount of rework. The production process also involves transferring parts between machines, which reduces labor productivity and increases material handling costs. Consequently, this leads to lower quality, longer waiting times, extensive work in progress, and increased material movement. To address these issues, the study suggests identifying areas that produce waste, determining bottleneck operations, and distinguishing between value-added and non-value-added time.

The following information is related to the production line:

The duration of each working shift is 8 hours and the total available time during each shift is 510 minutes. Two tea breaks are given during each shift, each lasting for 10 minutes, which adds up to a total of 20 minutes of break time. Additionally, there is a lunch break during each shift, which lasts for 30 minutes.

4. DEVELOPMENT OF CURRENT STATE MAP

Figure 2 displays the current state map created for the bearing cage manufacturer. The company receives orders from customers every month, but due to fluctuating demand, talk time was not calculated for this study. The production control department sends daily instructions to the production supervisor, who then communicates them to the relevant personnel. Manufacturing of the bearing cages involves 13 processes, each with a specific number of operators and cycle time, as detailed in Table 1.

Table 1: Process sequence with the number of operators required and cycle time

Sr. No.	Process in sequence	Number of operators	Cycle time (min)
1	Turning	1	3.3
2	Stress relieving	2	600
3	Pocketing	1	19
4	Deburring	1	1
5	Filling	1	2.5
6	Lathe spigot	1	1
7	Drilling		1
8	Reaming	1	0.5
9	Chamfering		0.5

10	Vibro	1	19
11	Visual inspection	1	3.5
12	Packaging	1	1
13	Final audit	1	9

The company operates on three shifts per day (each shift of eight hours duration with 30 minutes lunch break, 30 minutes of Jishu-Hozen time, and 20 minutes of tea break time (inclusive)).

The available or planned production time per shift is calculated as follows:

Planned time = (Total production time – planned downtime)
= (8*60) – (30+30+20)
= 430min

Further, Uptime is calculated by dividing the actual operating time by available time (for reference, the Uptime calculation of turning is given below)

$$\text{Uptime} = \frac{\text{Available time} - (\text{Changeover time})}{\text{Available time}}$$

$$= \frac{510 - (93)}{510}$$

$$= 0.8176 * 100\%$$
$$= 81.76\%$$

Further, throughput time and waiting time are calculated. Throughput time is = 3512 min, and waiting time is 2855 min. For sum of all processes, the value-added time is 25min, and the non-value-added time is 632min.

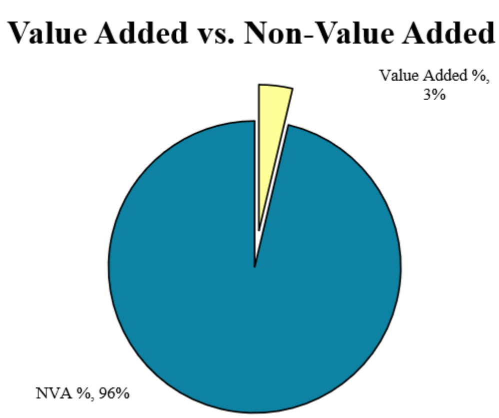


Figure 2: Graphical representation of value-added and non-value-added time for the current state map

After mapping out the process's current state, certain bottleneck areas were identified. Specifically, it was found that the flow of material was excessive across all 13 operations, and there was a significant amount of inventory buildup during the pocketing to vibro stage. Additionally, it was observed that the loading and unloading time for the VMC machine in the pocketing stage was 300 seconds. Still, the operators only spent 40 seconds doing this task. As a result, the operators believed they had a longer load-unload time than the actual loading time.

5. FUTURE STATE MAP

After analyzing the processes involved in the RHCRB product, the Future State map identified several areas where waste could be eliminated. In consultation with executives at the Bearing Cages Manufacturer company, proposals were developed to address these issues. The following are the identified problems in the Current State: high inventory levels between deburring and Vibro, excessive idle time for operators in Pocketing, Vibro, and SR (with 9.26 minutes, 8 minutes, and 60 minutes of idle time, respectively), high material movement between 13 processes, with a total movement time of 17 minutes, and long changeover times. To address these issues, proposals for waste elimination have been developed.

The proposals to improve the future state map

a) To reduce inventory in Pocketing to Vibro, continuous flow can be implemented. This will help to minimize the idle time in Pocketing. Currently, operators have an idle time of 9.26 minutes, but after implementing continuous flow, operators will have more time to engage in value-added activities such as deburring. This will help to decrease idle time and improve productivity.

b) To eliminate the bottleneck in Pocketing, the loading and unloading time in VMC has been reduced from 300 seconds to 140 seconds. As a result, instead of 300 seconds, operators now have only 120 seconds of loading and unloading time. This has helped to save 3 minutes and increase the daily output from 18 to 21 in one shift.

c) To reduce material movement between the 13 processes and minimize material traveling time, the layout of material movement has been redesigned. This will help to improve efficiency and optimize the flow of materials between operations. It is shown in Figure 5.

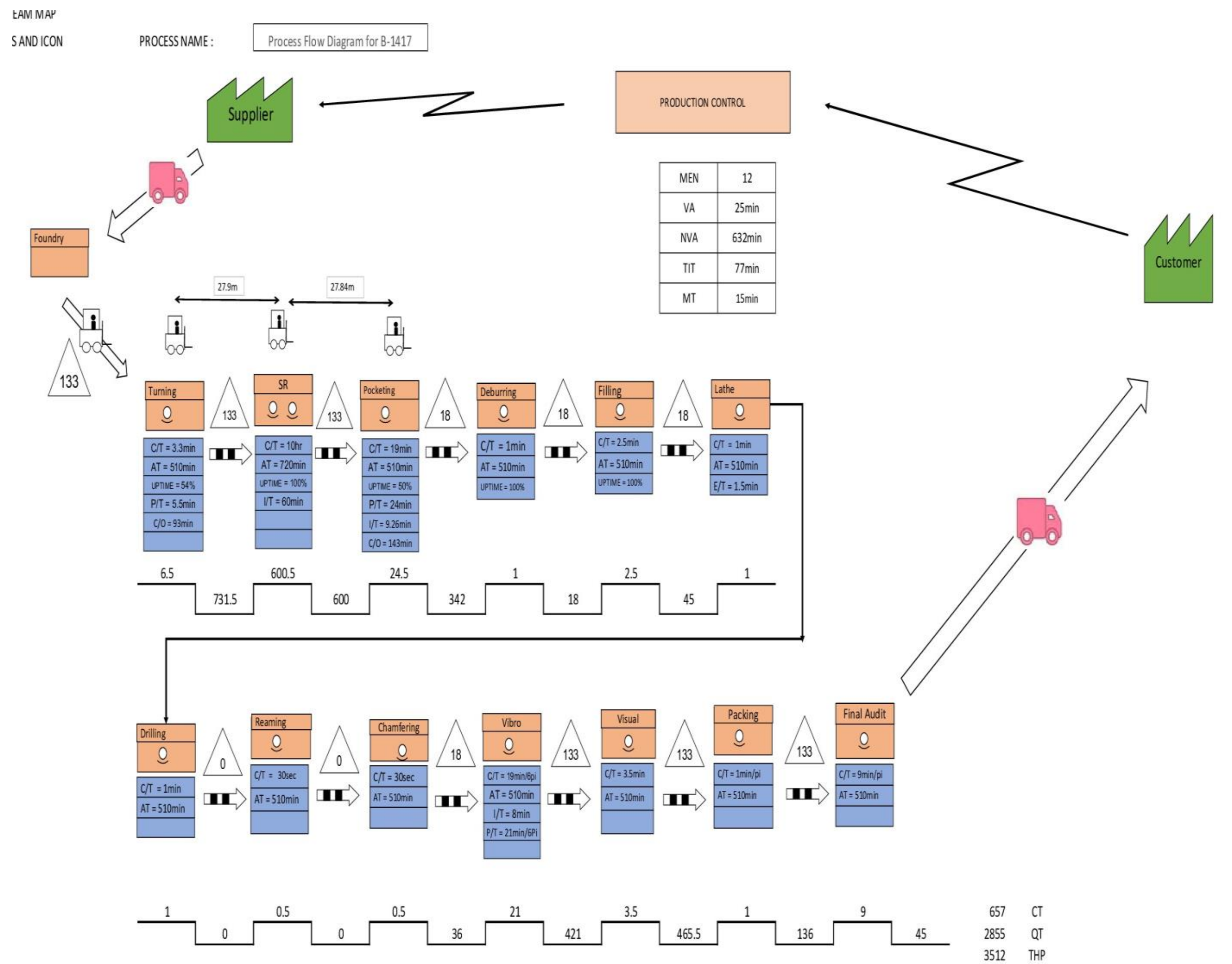


Figure 3: Current state map for bearing case manufacturing production line

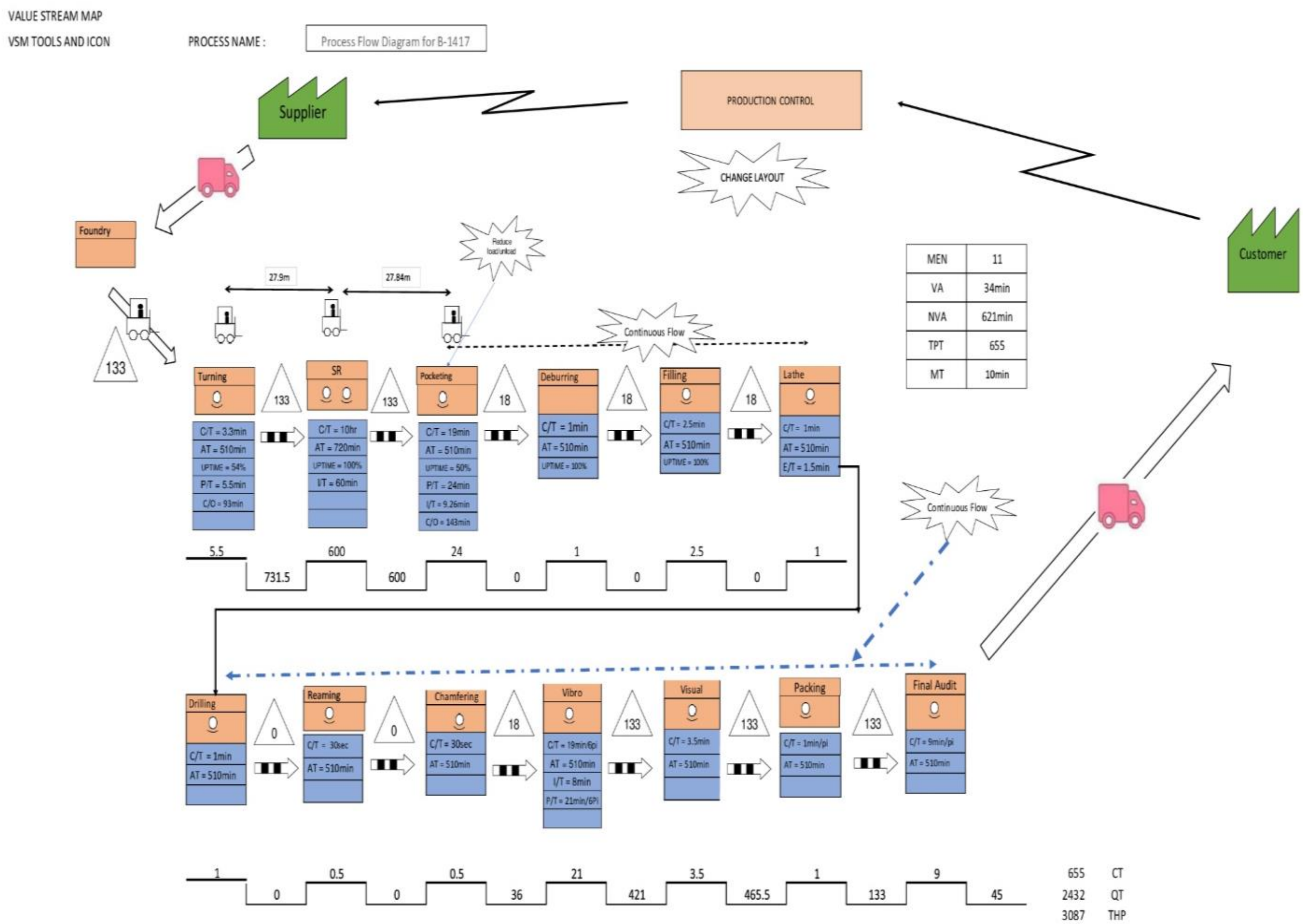
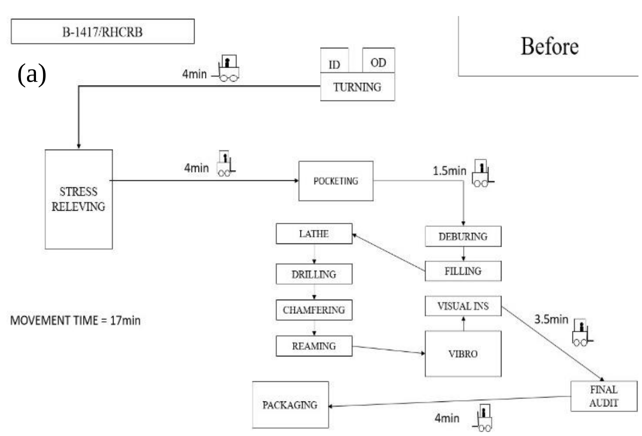


Figure 4: Future state map for bearing case manufacturing production line

6. RESULTS AND DISCUSSIONS

After the proposed implementation of continuous flow, queued time or waiting time of material is reduced from 2855 min to 2432 min., and Throughput time is reduced from 3512 min to 3087 min. Both throughput time and waiting time are essential metrics in VSM, as they help identify areas of waste in a process and provide insight into the overall efficiency and effectiveness of the process. By minimizing waiting time and optimizing throughput time, organizations improved their overall productivity and reduced costs. Also, non-value-added time for all activities decreased from 632 min to 621 min.



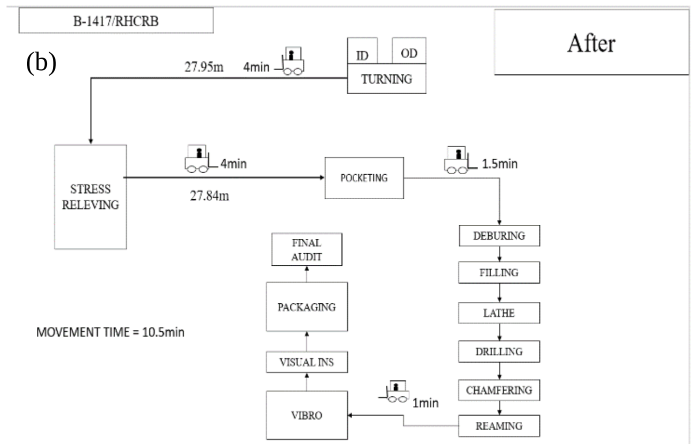


Figure 5: Material flow diagram (a) present layout, (b) future layout

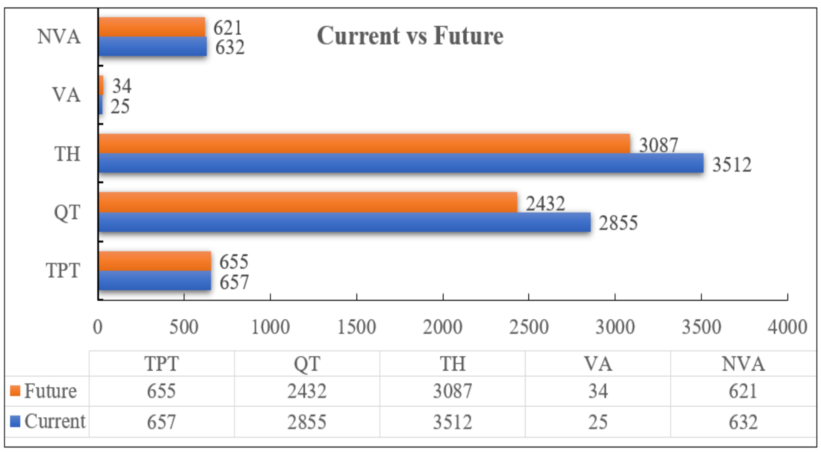


Figure 6: Comparison between current and future state map

7. CONCLUSION

- The conclusion of the analysis using Value Stream Mapping (VSM) is to create a more efficient and effective process that provides value to customers. By identifying areas of waste, inefficiencies, and opportunities for improvement in the current process, VSM enables organizations to design and implement a future state that eliminates waste, optimizes efficiency, and enhances quality. This leads to a streamlined process that provides the customer with value most efficiently and effectively possible. VSM also fosters a culture of continuous improvement, where the process is continually monitored and optimized to deliver value to the customer consistently.
- Following the proposed implementation, the value-added activity has increased by 2%, and the throughput time has decreased by 12%, indicating quantifiable benefits of the VSM process improvement.

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