Black Sea Journal of Engineering and Science
doi: 10.34248/bsengineering.1489166

Open Access Journal
e-ISSN: 2619 – 8991

Short Communications
Volume 7 - Issue 5: xxx-xxx / September 2024

IMPROVING LEAD TIME THROUGH LEAN MANUFACTURING: A CASE STUDY

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Abstract: Lean manufacturing is a well-established methodology aimed at optimizing production by eliminating waste, enabling industries to thrive in a globally competitive environment. This paper presents a case study of a well-known automotive manufacturing industry focusing on the axle process. This article demonstrates how the Value Stream Mapping (VSM) methodology was used in the axle process to reduce lead time by producing quality products with a reduction in non-value-added activities. The current state of the axle process was mapped using industry data from the past six months. Significant improvements were realized following the successful implementation of VSM, including a reduction in the lead time from 89.50 hours to 50.55 hours. The new state map was also created after implementing the improvements. The results illustrated that the VSM increased the effectiveness of the axle process by 56.48%.

Keywords: Lean principle, Process improvement, VSM, Waste

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Received: May 24, 2024
Accepted: July 24, 2024
Published: September 15, 2024

Cite as: Taş Ü. 2024. Improving lead time through lean manufacturing: A case study. BSJ Eng Sci, 7(5): xxx-xxx.

1. Introduction

The automotive industry plays a considerable role in manufacturing and assembly and immensely impacts various aspects of production (Yousaf et al., 2023). Industrialization is increasing as technology advances; however, rejection or rework remains a significant concern for the automotive sector. Lean manufacturing tackles these concerns through a continuous improvement system that integrates material and information flows within an industry. The goal is to identify and eliminate waste that negatively affects lead time, material costs, product quality, and other production factors (Jimenez et al., 2019). VSM is one of the most effective lean tools industries use to find and eliminate waste to reduce product costs, improving quality and efficiency (Atigre et al., 2017; Banica and Belu, 2019; Duggan, 2002). VSM is employed to enhance the flow of materials and information on the shop floor and to eliminate seven types of waste, including transportation, excess inventory, waiting time, unnecessary motion, overproduction, over-processing, and defects, as identified in manufacturing industries (Saboo et al., 2014). The axle in a vehicle is a crucial part of the drivetrain system, located at the rear end. It supports the axle, differential, and axle shafts, and is essential for bearing the vehicle's weight, transmitting power to the rear wheels, and providing a mounting point for the rear suspension. The protective structure encloses and supports the rear axle and its associated components, serving several important functions. The axle transmits power from the differential to the rear wheels, propelling the vehicle forward (Guleria et al., 2022; Ranjan et al., 2023).

Reviewing the literature, it is clear that VSM is a methodology used to reduce waste in most lean research publications. According to Rahani and Ashraf (2012), a significant amount of time spent in the production system is usually non-value-added. They also reported on the effectiveness of VSM in identifying hidden wastage and improving productivity. Belokar et al. (2012) reported that VSM is a highly useful tool for identifying and eliminating waste in a cycle, fostering a culture of lean practices. Rohani and Zahraee (2015) implemented VSM in the manufacturing industry's production line, reducing lead time from 8.5 days to 6 days. Romero and Arce (2017) found that implementing VSM can enhance the visibility of the value stream and boost manufacturer performance. Deshkar et al. (2018) used VSM in plastic bag manufacturing, reducing cycle time from 46 min to 26.6 min. Narke and Jayadeva (2020) implemented VSM, reducing setup time by a fixture and saving 336 hours per year. Operator fatigue was also significantly reduced. Guleria et al. (2022) claimed that the rejection rate in the rear axle process was reduced from 10.4% to 3.20% after implementing Lean Six Sigma. Badhotiya et al. (2023) with the new map show a possibility of a 62.65% reduction in total transportation time in the equipment industry.

VSM is a valuable tool for improving industry efficiency. However, many industries and literature do not frequently use VSM due to a lack of awareness compared to other lean tools. This field lacks sufficient case studies, making this study original. Previous research has not adequately addressed VSM as a case study, resulting in inadequate case studies. This study is uncommon in filling this gap in the field. To contribute to the relevant literature and industry, this article presents a case study of the axle manufacturing industry. It discusses how the assembly line created a new status by reducing the lead time of the axle process through waste elimination. Hence, this article aims the VSM methodology was used in the axle process to reduce lead time by producing quality products with a reduction in non-value-added activities.

2. Materials and Methods

An established automotive manufacturing company has been selected to study and implement VSM. This company is a global player in the production of passenger cars, trucks, and buses worldwide. It operates in three shifts and has a workforce of 2,000+ manpower. Like other companies in the industry, this company has faced challenges related to long lead times in axles. The VSM methodology was selected to identify and eliminate waste in the axle production process.

The research was based on actual data and outlined the steps used in the VSM process. It analyzed improvement steps taken based on data and waste elimination by a team of managers, engineers, and a researcher. Data was collected from the axle assembly line, which included 6 processes pre-assembly, LPH assembly, cable assembly, balance shaft assembly, cast console assembly, and tightening.

The stages of the case study can be summarized as the selection of the bottleneck, drawing the current state map, analysis, and creating a new state map.

3. Case Study and Discussion

This case study was carried out in an automotive manufacturing company. Axles are supplied and disassembled from the supplier in quantities of 462 pieces per week. Current status, 77 units of axles, each consisting of 6 processes (pre-assembly, LPH assembly, cable assembly, balance shaft assembly, cast console assembly, and tightening) are produced per day. Sample axle types and axle displays in vehicles are shown in Figure 1.

Figure 1. Sample axle types and axle displays in vehicles.

Following the assembly of each axle, one axle is installed on every vehicle. Annually, approximately 28,000 vehicles are produced.

VSM was selected to find and eliminate the wastage in the axle process. VSM is followed in the following steps i.e.;

- Selection of bottleneck: The VSM applies to a bottleneck in the axle process in this study. Accordingly, the product axle with the maximum lead time was selected for the study.
- Current state map: The state map was created using six months of historical data on axle products. The case study was conducted as a historical document review to compile the necessary data for the current situation analysis. Current status problems included; (a) forklift transfers in internal logistics; (b) over-processing; (c) over-manpower; (d) over-waiting time; (e) unnecessary motion; and (f) decreased inventory level. VSM's current status, from the supplier to the customer, and the problems were illustrated with universal symbols in Figure 2.

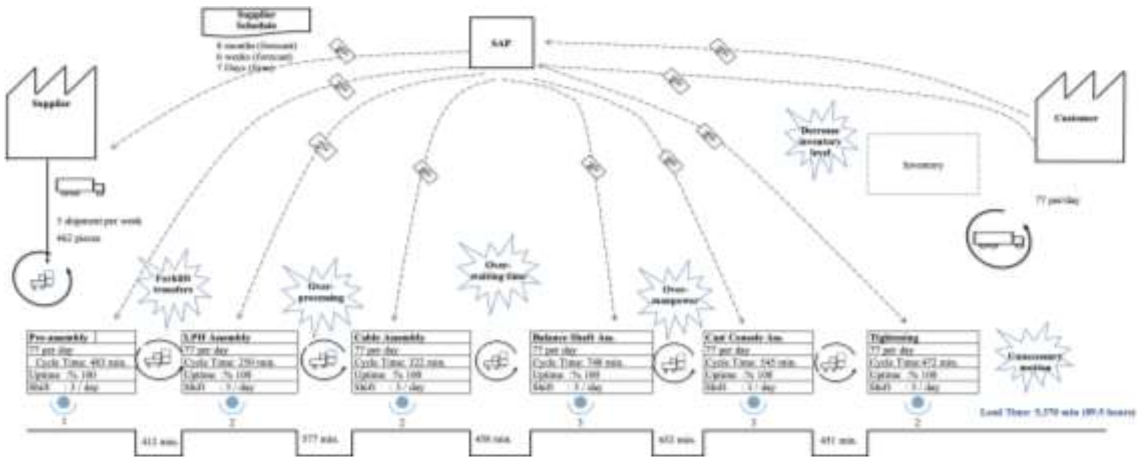

Figure 2. Current state map.

In VSM's current status, the delivery time from the supplier to the customer is 89.50 hours. During production, each vehicle has at least one axle mounted after its front assembly. The axle is a crucial component of the vehicle, and all vehicles complete their final assembly and come off the line on their wheels. Currently, 77 units of axles, each consisting of 6 processes including pre-assembly, are produced per day.

- Analyze: Forklift transfers in internal logistics, over-processing, over-manpower, over-waiting time, unnecessary motion, and decreased inventory level were the six major sources of waste identified after the current state map. To improve axle assembly, the decision was made to replace forklifts with unmanned vehicles or energy-saving wheelbarrows for material transportation. LPH assembly and Cable assembly processes were combined, streamlining the assembly into a single process. The number of operators has been reduced by combining processes, reducing forklifts, and reducing cycle times. With the use of Automated Guided Vehicle (AGV) and wheelbarrows and the decrease in the number of operators, waiting times have decreased. Finally, unnecessary motions have been eliminated by reducing the number of operators and forklift activities.
- New state map: A new state map was created to show the improved net lead time of the axle process. The VSM new state map represented demonstrating the enhanced optimal state of the processes in Figure 3.

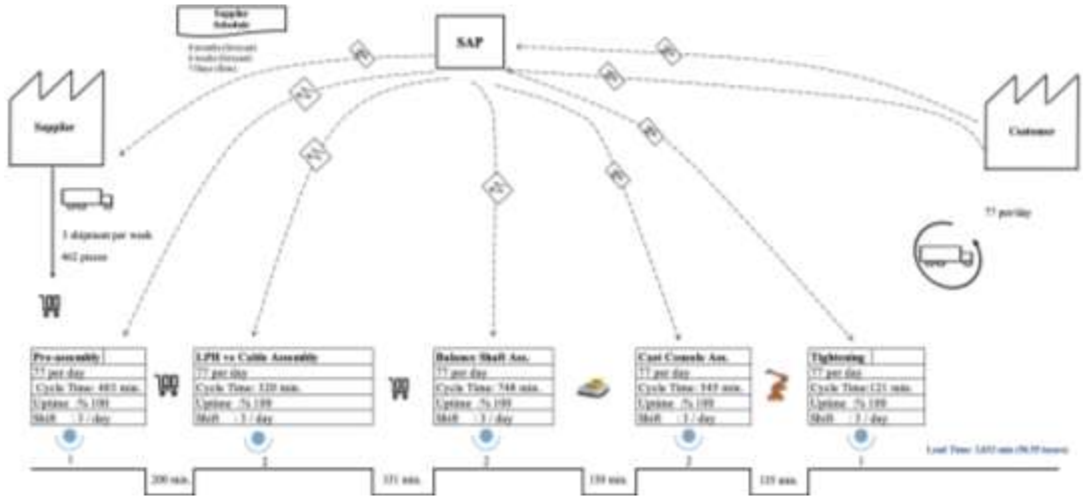

Figure 3. New state map.

The contribution of the VSM was to identify the wastages of the current status and to improve the new status. VSM's new status, the lead time from the supplier to the customer is 50.55 hours. The new status was applied to identify the ways to improve the axle process improvements using the VSM while achieving the operational excellence. According to new status, the improvements were identified as follows;

a) Forklift transfers in internal logistics: In order to improve the axle assembly process, the decision was made to replace forklifts with AGVs and energy-saving wheelbarrows for material transportation. The cycle time has been reduced by replacing the currently used forklifts with AGVs and wheelbarrows. While 6 forklift operators are in their current status working, in this way, the number of wheelbarrow operators has reduced to 3. AGVs are capable of reducing the cost of forklifts and their operators and can operate 24 hours a day, 7 days a week, without any operator supervision.

b) Over-processing: After analyzing the current situation, it has been decided to combine LPH and cable assembly into a single process to enhance cycle time and operator efficiency. By merging the LPH and cable assembly processes, the cycle time has been reduced from 572 minutes in the current status to 320 minutes in the new status.

c) Over-manpower: The current status, while 13 operators are working in the process, the number of operators has been reduced to 8 with the reduction of non-value-added activities.

d) Over-waiting time: Waiting times have been eliminated as cycle times decreased from 2,820 minutes to 2,217 minutes due to process mergers, reduced transportation times, and a decrease in the number of operators.

e) Unnecessary motion: Unnecessary motions have been eliminated by reducing the number of operators and forklift activities, it was decreased from 2,550 minutes to 816 minutes.

f) Decreased inventory level: After completing the final process, it was removed out an area of approximately 720 m^2 by removing the safety stock of 8 vehicles and shipping them directly to the customer from the production line. As a result, non-value-added movements have decreased, and it has saved space in the area.

The application of VSM to evaluate the expected effects in the lead time process resulted in improvements as follows. Table 1 illustrates the comparison between the current and new situations.

Findings from this case study show that with the application of VSM methodologies, significant improvements were achieved in the axle processes from the entrance warehouse to the customers. The success of the VSM application depends on the results of the case study. Based on the improvements in VSM, the lead time, which was 89.50 hours in the current situation, has been reduced to 50.55 hours in the new situation, resulting in a reduction of approximately 56.48%. In the new status, the cycle time has been dramatically reduced compared to the current status.

Table 1. VSM improvements

Waste	Current Status	Future Status
Transfers in internal logistics	6 forklifts	3 wheelbarrows, 2 AGVs
Over-processing	6 process	5 process
Over-manpower	13 operator	8 operator
Over-waiting time	2820 min.	2217 min.
Unnecessary motion	2,550 min.	816 min.
Decreased inventory level	8 vehicle	0
Total	5370 min.	3033 min.
	89.50 hours	50.55 hours
Improvements	56.48%	

4. Conclusion

VSM is a crucial tool in lean manufacturing, and it has been applied in the automotive industry to analyze the axle manufacturing process in a specific case study. This article focuses on how the VSM methodology was used to optimize the axle process, aiming to reduce lead time, eliminate non-value-added activities, and ensure the production of high-quality products.

Upon analyzing the current state map, it became evident that non-value-added time, such as transportation and waiting time, could be significantly reduced to enhance productivity. After conducting a detailed analysis of the current state map and consulting with team members and operators, changes were implemented to improve the process. As a result of the successful implementation of VSM, the lead time was reduced from 89.50 hours to 50.55 hours. This led to a considerable reduction in operator fatigue and successfully achieved the goal of increasing lead time efficiency. A new status map was created to reflect the implemented improvements. The results demonstrated that the VSM improved process effectiveness by 56.48% in the axle manufacturing process. This improvement resulted in reduced internal logistics, decreased over-processing, over-manpower, over-waiting time, unnecessary motion, and a decreased in inventory levels through process enhancements.

Author Contributions

The percentage of the author(s) contributions is presented below. The author reviewed and approved the final version of the manuscript.

	Ü.T.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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