Application of Lean Tools for Reduction of Manufacturing Lead Time

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Abstract. In the recent years, manufacturing industries are trying to improve customer service by reducing wastes, reducing lead time, improving quality and improving productivity using lean tools. Value Stream Mapping is one of the lean tools for analyzing the current state and designing a future state for the series of events that take a product from its beginning through delivery to the customer. The goal of this study is to apply Value Stream Mapping in production line of Fuel tank semi trailers at XYZ PLC Metal Industry for reducing the manufacturing lead time. In this case study, the existing state of the production line is mapped with the help of Value Stream Mapping process symbols and the biggest improvement areas like excessive work in process and long lead time are identified. Some improvements in current state Value Stream Mapping are suggested and with these improvements future state Value Stream Mapping is developed. Current state and future state of the production line are compared; the results show that 47.45% reduction in lead time, 50.2% reduction in work in process time, 59.2% reduction in total waiting time, 72.72% reduction in number of work in process products, 7% reduction in number of workers and over 89.65% increase in the yearly throughput of products.

Keywords: Manufacturing lead time · Value stream mapping · Lean tools

1 Introduction

In this competitive world, the competitive edge of manufacturing industries depends largely on their ability of delivering their goods at low cost and high quality to customers [1]. To achieve this edge, manufacturing industries use lean tools because of their systematic approach in manufacturing waste and lead time reduction. Value Stream Mapping is a powerful lean tool that combines material processing steps with information flow as well as other important related data. The ultimate goal of Value Stream Mapping is identifying and eliminating the different types of wastes in the production line in order to increase its efficiency and productivity. This paper presents a case study on the application of Value Stream Mapping in one of the metal industries in Ethiopia facing different problems related to overall work efficiency, throughput and production lead time. It addresses the implementation of lean manufacturing in the production line of Fuel tank semi trailers with a focus on analyzing the processes; identifying and minimizing wastes and reducing the manufacturing lead time.

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2 Literature Review

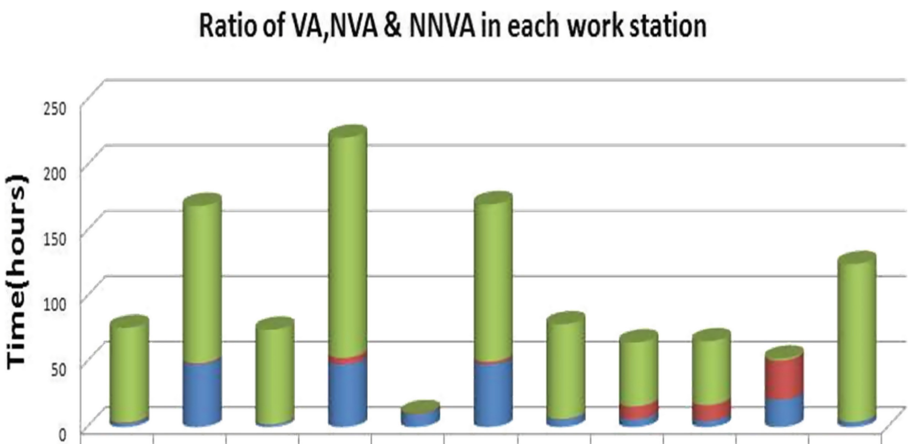
Lean manufacturing is a systematic method for waste minimization within a manufacturing system without sacrificing productivity. Lean also takes into account waste created through overburden and waste created through unevenness in workloads. Working from the perspective of the client who consumes a product or service, value is any action or process that a customer would be willing to pay for. Lean manufacturing has different tools like Value Stream Mapping, Single-minute exchange of die (SMED), Five S, Kanban, poka-yoke (error-proofing), total productive maintenance, kaizen, cellular manufacturing, standardized work and one piece flow that assist in the identification and steady elimination of waste. As waste is eliminated; quality improves while production time and cost are reduced. Today the use of lean tools in the manufacturing world has been increased because of their capability in manufacturing waste and lead time reduction. Value Stream Mapping is a lean tool that helps users see and understand the flow of material and information as products make their way through the value stream [2]. The value stream includes the value adding and non value-adding activities that are required to bring a product from raw material through delivery to the customer. According to Hines and Rich [3] value stream includes the complete value added as well as non-value added activities, from conception of requirement back through to raw material source and back again to the consumer's receipt of product. Jones and Womack [4] explain Value Stream Mapping as the process of visually mapping the existing stage of manufacturing as it now occurs and preparing a future state map with better methods and performance. Singh et al. [6] have carried out a case study to identify areas of wastes in manufacturing of components to meet the maintenance need of diesel traction fleet, Indian railways. They have tried to discuss the lean implementation process with the help of Value Stream Mapping. As a result many benefits are reported such as reduction in lead time by 83.14%, reduction in processing time by 12.62%, reduction in Work in process inventory by 89.47%, reduction in manpower requirement by 30% and rise in productivity per operator by 42.86%. Vinodh et al. [7] apply Value Stream Mapping for enabling leanness in the manufacturing process of stiffer camshaft in an Indian camshaft manufacturing organization. As a result, idle time has been decreased from 19,660 to 19,449 min; total cycle time has been reduced from 539 to 525 min, number of work-in-progress inventory has been reduced from 4,660 to 4,610 units. On time delivery of products has been improved from 70% to 85%. Defects have been reduced by 4% and uptime has been increased by 1.72%. Seth and Gupta [8] have made an attempt to use Value Stream Mapping as a technique to achieve productivity improvement at supplier end for an auto industry. They reported a reduction in number of work in process inventory and finished goods inventory as well as an improvement in production output per person. Like these promising studies the authors were provoked to conduct this study with the lean tools in one of the metal industries in Ethiopia to reduce the manufacturing lead time.

3 Research Methodology

To conduct this case study research we start with the review of different research works on lean manufacturing and Value Stream Mapping applications in manufacturing industries. This is followed by identification of critical shop floor and selection of a product for the case study. And then, all important data related to the product such as material & information flow, cycle time, value added time and non-value added time for each process has been collected and current state Value Stream Mapping has been developed to show the existing status of the selected production line. Then the current state Value Stream Mapping has been analyzed; some improvements are suggested and with these process improvements a future state Value Stream Mapping is prepared to design a lean process flow.

4 Case Study

The case study has been carried out at XYZ PLC Metal Industry located in Mekelle, Ethiopia. The company deals with manufacturing of truck mounted fuel tankers, 2 axle; 3 axle dry cargo trailers and semitrailers for transporting heavy duty equipment. Truck mounted fuel tanker has been chosen as the candidate product for the case study. The reason behind the selection of this product family is that they have high volume of production; high number of manufacturing processes over the others and are highly demanded by the customers when compared to other family of products. Figure 1



	Cutting	welding	rolling	assembly	Water test	mounting	Sanding	Anti rust	Stucco	Color	finishing
NVA	72.3	120.2	72.25	168.25	0	120.4	72.3	48.8	48.66	1.45	120.5
NNVA	0.65	0.88	0.25	5	0.75	2	0.33	10	12	30	0.15
VA	3	48	2	48	10	48	6	6	5	21	4

Fig. 1. Ratio of value added time, non value added time and necessary non value added time in each work station

shows us the amount of value added time, necessary non value added time and non value added times in each work station of Fuel tank semi trailers production line.

As it is shown in Fig. 1, there is a high amount of waiting time or non value added time in each work station. So by reducing this waiting time or non value added time, the manufacturing lead time can be reduced. The pie chart below displays the contribution of value added time, non value added time and necessary non value added time to a total time of the current Fuel tank semi trailers production line (Fig. 2).

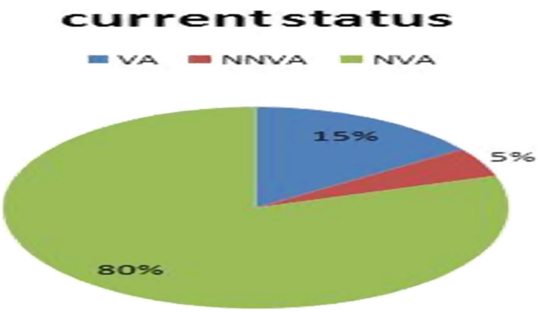


Fig. 2. Percentage of value added time, non value added time and necessary non value added time in the production line

This study continues with mapping of current state of Fuel tank semi trailers production line. The mapping is done in software using various process symbols of Value Stream Mapping to visualize the flow of material and information as the product takes its way in the production line. Mapping is carried out keeping in view of the lean manufacturing principles as discussed by Rother and Shook [5] and Seth and Gupta [6]. These principles are: define value from your customer's perspective; identify the value stream; eliminate the seven deadly wastes; make the work flow; pull the work rather than push it; and pursue to perfection level. So the main idea of this work is to give a clear view of how lean practices and Value Stream Mapping can be applied to a production line of Fuel tank semi trailers to reduce manufacturing lead time.

5 Results and Discussion

5.1 Current State Value Stream Mapping

Value Stream Mapping helps in visualization of station cycle times, inventory buffers, material and information flows in the entire transformation of a product from raw material to the end product. Figure 4 shows a Value Stream Mapping that indicates a pictorial representation of the data for the Fuel tank semi trailers production line. The timeline at the bottom of the map shows the value added and non value added times. The rectangle blocks represent process stations, the triangles represent the waiting times at each process station. The figure inside the rectangular box represents the average value added time and the figures under the triangles in-between process stations represent the non-value added time. The cycle time is calculated in hours/batch. The available time is calculated based on regular production time of 8 h per shift. As it is shown in the timeline of the current state value stream mapping, the total task time or cycle time of the fuel tanker is 263.01 h consisting of 201 h of value added time and 62.01 h of necessary non-value added time. This indicates that the fuel tanker spends a total of 263.01 h being processed at different work stations. The fuel tanker also stays for about 1252.3 h as work in process product starting from the cutting station to the last finishing work station. There is a total of 1059.9 h of waiting time through all stations that indicates the average waiting time of the fuel tanker per work station is about 96.51 h. The sum of the value added and non-value added time also known as the lead time is also calculated to be 1324.6 h. This means a single fuel tanker that could be made in 263.01 h is taking 1324.6 h to be produced due to non value added activities in the current state Value Stream Mapping. The total distance travelled by the worker and materials in the current production process is also calculated to be 1787 m. The Takt time; the rate at which one product has to come out of the manufacturer to meet the customer demand is calculated to be 53.5 h by dividing the available working hours per year which is 5940 h to customer requirement of products per year which is 111 fuel tankers. The comparison analysis of Takt time and cycle time of the processes is shown in figure below (Fig. 3).

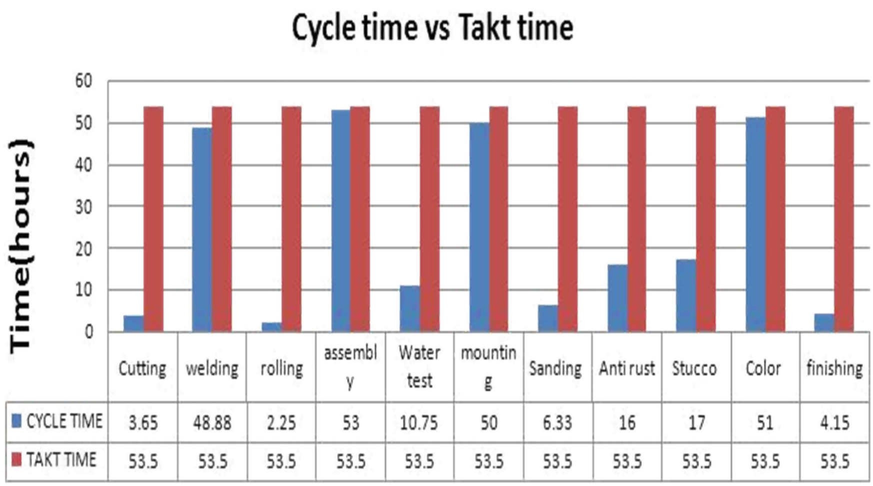


Fig. 3. Takt time versus cycle time before improvement

As the graph shows, the production line is not balanced because the tasks are not uniformly distributed among the work stations. In some of the work stations, there is a lot of free time for workers. This shows that the line is capable of making more products but there is a need to have the line balanced. The line balancing efficiency for the workloads at the eleven work stations of the production line is calculated as the ratio of total processing time and the value of multiplication of actual workstation number with the largest assigned cycle time. The total processing time is equivalent to

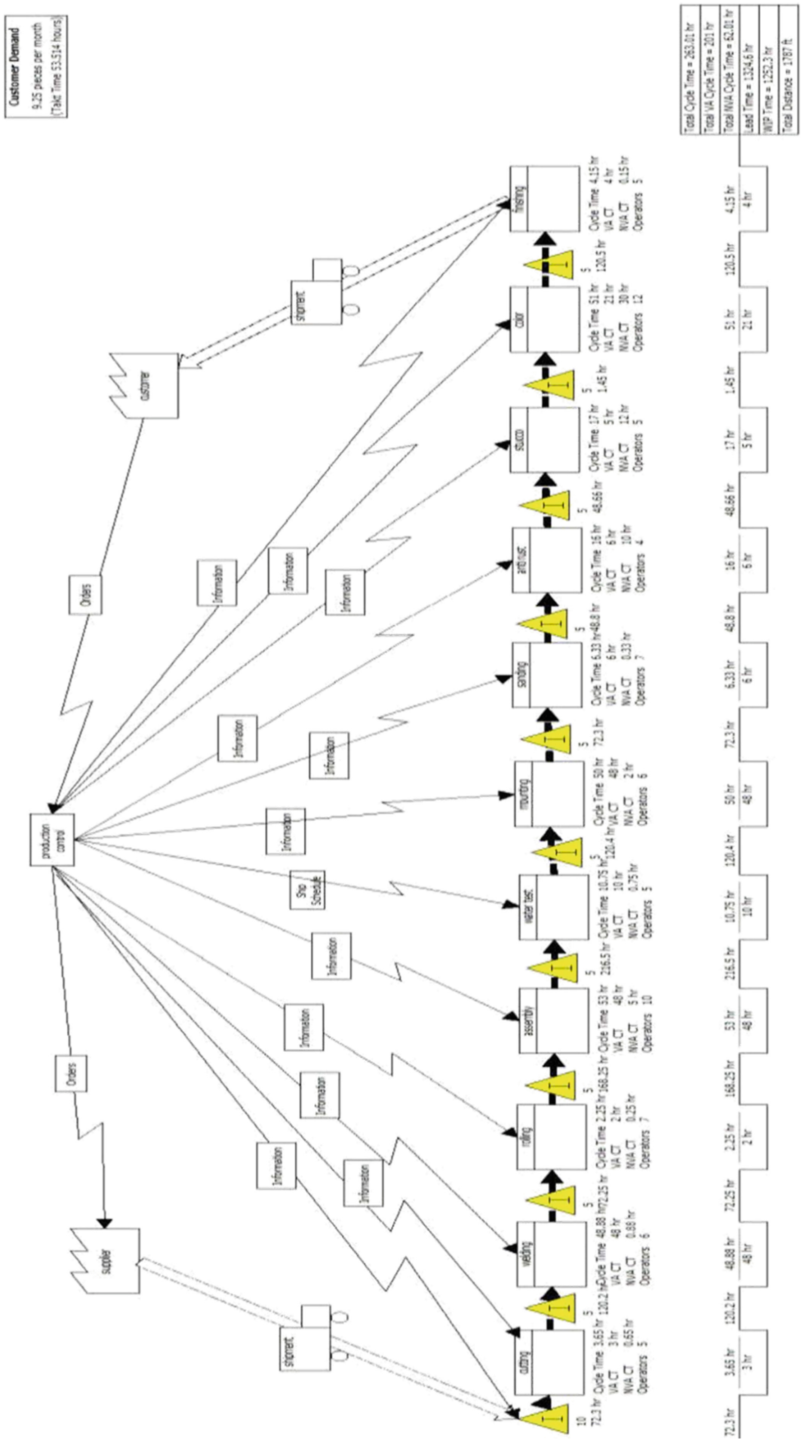


Fig. 4. Current state value stream mapping

the sum of the operation cycle times which gives 263 h whereas the actual number of workstations is 11 and the largest assigned cycle time is 53 h (assembly work station). Thus, the line balancing efficiency is found to be 45.1% as calculated below.

$$\begin{gathered}\text{Line balancing efficiency} \\ = \sum \text{Total processing time}/(\text{No of stations} * \text{Longest processing time}) \\ \text{Line balancing efficiency} = 263\,\text{h}/(11 * 53\,\text{h}) \\ \text{Line balancing efficiency} = 45.1\%\end{gathered} \tag{1}$$

Once the current state Value Stream Mapping is completed, the next step is to look for possible improvements and start outlining a future state Value Stream Mapping. The main goal of developing future state Value Stream Mapping is to eliminate identified wastes and make a continuous and smooth flow that generates shortest lead-time, highest quality and lowest cost. Different types of wastes have been identified from the current state Value Stream Mapping. The identified wastes have been reduced by applying different lean tools such as line balancing and First in First Out rule to prepare a future state Value Stream Mapping. The Future State Value Stream Mapping shows how the shop floor will operate after lean improvements are implemented.

5.2 Combining Similar Operations and Line Balancing

In sanding, anti rust, stucco and painting work stations; the cycle time and the number of operators were high. So to reduce that, the operations have been combined to be performed in one big work station by balancing the line; and the sanding operation has been started to be performed by the workers of anti rust and stucco painting work stations since it takes a small amount of time. As a result, the number of workers has been reduced from 72 to 67. The comparison analysis of Takt time and cycle time of processes after balancing the line is shown in figure below.

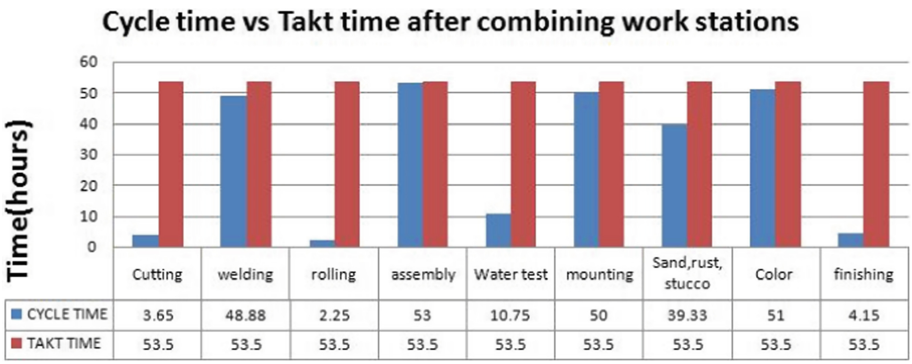


Fig. 5. Takt time versus cycle time after combining work stations

As it is shown in Fig. 5, the tasks are uniformly distributed among work stations and the line is balanced with all processes. This means that the line is capable of making more products than before and on the basis of the collected processing time data, line balancing efficiency is calculated to see the improvements in the proposed state of a value Stream. The total processing time is equivalent to the sum of the operation cycle times which gives 263 h whereas the actual number of workstation is nine as a result of combining the sanding, antirust and stucco operations to be performed in one work station and the largest assigned cycle time is 53 h (assembly work station). Thus, the line balancing efficiency is found to be 55.13% as calculated below.

$$\begin{gathered}\text{Line balancing efficiency}\\ = \sum \text{Total processing time}/(\text{no of stations} * \text{longest processing time})\\ \text{Line balancing efficiency} = 263\,\text{h}/(9 * 53\,\text{h})\\ \text{Line balancing efficiency} = 55.13\%\end{gathered} \tag{2}$$

From the above result, the improved line balancing efficiency of the production line is 55.13%. This result is better in comparison with the previous line balancing efficiency but there is a room for improvement of the production line using other lean tools and techniques.

5.3 One Piece Flow and First in First Out (FIFO) Techniques

One piece flow means components are produced one by one, and each component progresses instantly from one operation to the next without having to wait in a buffer. In the current production process, the product passes through the work stations in a batch mode. This results in high travelling distance, high lead time and high work in process time. In order to keep the flow continuous that leads to reduction in buffer time, one piece flow and FIFO technique have been applied. One piece flow technique has been applied in the production line to transfer the products from one station to another station one by one rather than in a batch in order to eliminate all the waste. The FIFO technique has been also applied to process and deliver the products to the next station in the same order they entered the first work station. This results in clear and smooth flow with reduced waiting time and reduced inventory (Fig. 6).

In the developed future state value stream mapping, one piece flow and First in First out techniques have been implemented to reduce the inventory time and lead time. As a result, Information flow is improved and Entire system is converted from push system to pull system. After these lean techniques are applied, the software automatically calculated the improved performance indicators result as follows. The time the fuel tanker spends as work in process product starting from the cutting station to the finishing station has been reduced from 1252.3 h to 623.71 h; the total waiting time (work in process inventory time) between stations has been reduced from 1060 h to 432.74 h. This means the average waiting time of the fuel tanker per work station has been reduced from 96.51 h to 39.36 h and the sum of the value added and non-value added time also known as the lead time has been reduced from 1324.6 h to 696.01 h by combining similar operations, balancing the line and applying FIFO rule. This indicates that a single fuel tanker that could be made in 263.01 h is taking 696.01 h to be produced in the improved Value Stream Mapping. The total travelled distance between stations has been also reduced from 1787 m to 1017 m. As it is observed from the result of the Value Stream Mapping, every unit of fuel tanker come out with in 53.5 h's

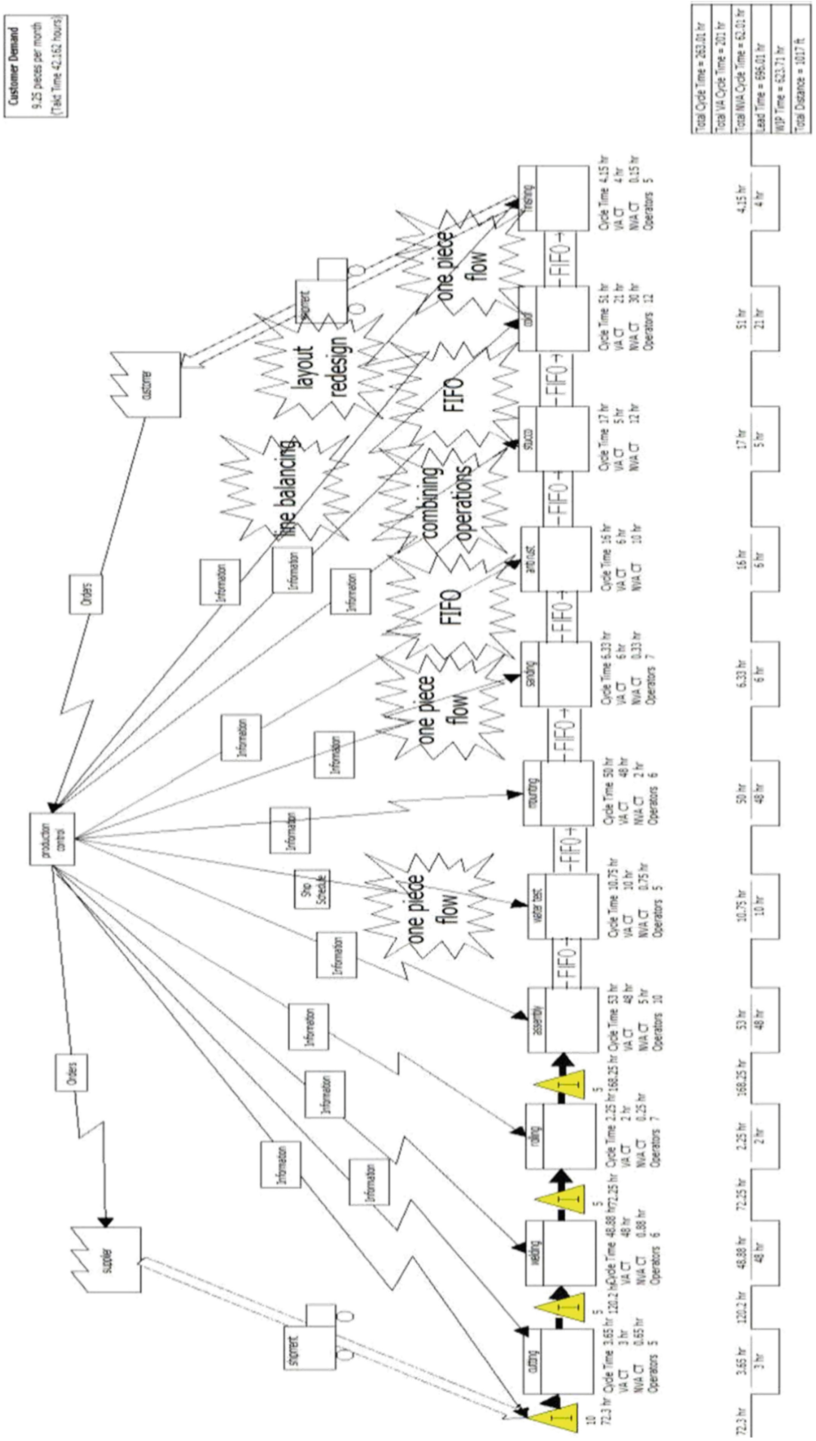


Fig. 6. Future state value stream mapping after lean tools implementation

interval and the line balancing efficiency has been improved from 45.13% to 55.13% by combining similar operations.

6 Conclusion

The goal of this paper was to reduce manufacturing lead time in the production line of Fuel tank semi trailers at XYZ PLC Metal Industry using Value Stream Mapping and other lean approaches. Based on the findings of the research; comparison between the current state and future state of the production line was made. The results show that 47.45% reduction in lead time, 50.2% reduction in work in process time, 59.2% reduction in total waiting time, 72.72% reduction in number of work in process products, 7% reduction in number of workers and over 89.65% increase in the yearly throughput of products. Hence, from the findings of this research it can be concluded that Value Stream Mapping and other lean tools are effective tools for identifying and reducing the non-value added activities, shortening the lead time for on-time delivery of products and enabling the companies to move towards their ultimate goal leading to profitability.

References

1. Onesime, O.C.T., Xu, X., Zhan, D.: A decision support system for supplier selection process. Int. J. Inf. Technol. Decis. Mak. **03**, 453 (2004). http://www.worldscientific.com/doi/abs/10.1142/S0219622004001197#citedBySection
2. Lovelle, J.: Mapping the value stream. IIE Solut. **33**(2) (2001). http://proquest.umi.com/pqdweb?did=68597087&sid=3&Fmt=4&clientId=10342&RQT=309&VName=PQD
3. Hines, P., Rich, N.: The seven value stream mapping tools. Int. J. Oper. Prod. Manag. **17**(1), 46–64 (1997). https://doi.org/10.1108/01443579710157989
4. Jones, D., Womack, J.: Seeing the Whole: Mapping the Extended Value Stream. Lean Enterprise Institute, Massachusetts (2000)
5. Rother, M., Shook, J.: Learning to See–Value-Stream Mapping to Create Value and Eliminate Muda, pp. 1–4. Lean Enterprise Institute, Cambridge (2009)
6. Singh, B., Garg, S.K., Sharma, S.K., Grewal, C.: Lean implementation and its benefits to production industry. Int. J. Lean Six Sigma **1**(2), 157–168 (2010). https://doi.org/10.1108/20401461011049520
7. Vinodh, S., Arvind, K.R., Somanaathan, M.: Application of value stream mapping in an Indian camshaft manufacturing organization. J. Manuf. Technol. Manag. **21**(7), 888–900 (2010). https://doi.org/10.1108/17410381011077973
8. Seth, D., Gupta, V.: Application of value stream mapping for lean operations and cycle time reduction: an Indian case study. Prod. Plan. Control. **16**(1), 44–59 (2005)