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# Application of lean manufacturing using value stream mapping in an auto-parts manufacturing unit

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## Abstract

**Purpose** – This paper aims to address the application of lean manufacturing using value stream mapping (VSM) concepts in an auto-parts manufacturing organization. Using value stream concepts, both current and future states maps of the organization's shop floor scenarios have been discussed to identify sources of waste between the existing state and the proposed state of the selected organization for improving its competitiveness.

**Design/methodology/approach** – VSM process symbols were used to discuss lean implementation stages in the auto-parts manufacturing unit. Current states of the selected manufacturing unit were prepared with the help of VSM symbols and improvement areas were identified. A few modifications in current state were made and, with these modifications, a future state map is suggested.

**Findings** – After comparison of the current and future states of the selected manufacturing unit, it has been found that there was 69.41 percent reduction in cycle time, 18.26 percent reduction in work in-process inventory and 24.56 percent reduction in production lead times for the replacement ball product. While for Weldon ball end product 51.87 percent reduction in cycle time, 21.51 percent reduction in work in-process inventory, 25.88 percent reduction in lead time was noted.

**Research limitations/implications** – The findings of this case study are valid due to limited selection of products only.

**Originality/value** – This paper depicts a true picture of the implementation of lean manufacturing tools in an organization.

**Keywords** Lean manufacturing, Value stream mapping, Production lead time, In-process inventory, Cycle time, Lean production, Lead times, Distribution and inventory management, Automotive components industry

**Paper type** Case study

## 1. Introduction

In recent times, many organizations have attempted to implement or have already implemented lean manufacturing (LM). Some companies have implemented a few tools/techniques/practices/procedures (i.e. "elements" in short) of LM, while others have implemented a whole spectrum of LM elements (Gurumurthy and Kodali, 2009). The concept LM was originated in Japan after the Second World War when it was realized that they could not afford to invest much now. The objective of LM is to reduce waste in every part (such as human effort, inventory, time to market and manufacturing space) to become more responsive to customer demand while producing quality products in the most efficient and economical manner (Womack *et al.*, 1990).

LM encompasses many different strategies and activities that are familiar to almost all industrial engineers (Braglia *et al.*, 2006; Chitturi *et al.*, 2007; Mahapatra and Mohanty, 2007). In many such cases, firms have reported some benefits by applying

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lean principles; however, it is apparent that there is a need to understand the entire system in order to gain maximum benefits (Singh *et al.*, 2010). Value stream mapping (VSM) acts as one of enterprise improvement tool in LM to assist in visualizing the entire production process, representing both material and information flow. The goal is to identify all types of waste in the value stream and to take necessary steps to eliminate them (Rother and Shook, 1999; Sahoo *et al.*, 2008; Seth *et al.*, 2008). VSM aids in the development of a "current state map" which shows a visual representation of how the company is currently operating; it records process information and information flow which can be used to identify key wastes, problems and opportunities. Once the current state map has been analyzed the future state map can then be produced to show how the company could operate more effectively (Pavnaskar *et al.*, 2003). According to the lean system, Lasa *et al.* (2008) showed that VSM is a valuable tool for redesigning of the productive systems and found that there are some key points for the establishing teams that have to take into account for designing of suitable information systems.

One of the major challenges for manufacturing industry is to manufacture variety products with a minimum lead time, reduced inventory and world class quality. There is a need to help the manufacturing companies to improve their competitiveness. Vinodh *et al.* (2012) applied the analytic hierarchy process typical multi-criterion decision-making method in a manufacturing organization for improving the leanness of the company. Many managers and researchers such as Hines *et al.* (1998), Hines (1999), Abdulmalek and Rajgopal (2007), Serrano *et al.* (2008) and Singh *et al.* (2009) applied VSM for identification and elimination of waste in production industry. In this paper, an attempt has been made to discuss lean implementation principles using VSM in ABC auto-parts manufacturing unit, located near Ludhiana, Punjab, India. There are ten different categories of products. Out of which, only two products named Weldon ball end and replacement ball is selected on the basis of lead-time problem. Current and future state maps of both the products have been made using VSM techniques. Rest of the paper is as follows.

Section 2 reports the concept of VSM. Section 3 explains the case study of an organization. Finally, Section 4 concludes by narrating the contributions of the present research.

## 2. VSM

VSM is a significant tool of LM. VSM can serve as a good starting point for any enterprise that wants to be lean. VSM was initially developed in 1995 with an underlying rationale for the collection and use of the suite of tools as being "to help researchers or practitioners to identify waste in individual value streams and, hence, find an appropriate route to its removal" (Hines and Rich, 1997).

Jones and Womack (2000) defined VSM as the process of visually mapping the flow of information and material for preparing a future state map with better methods and performance. The VSM includes two flows. One is the flow of resources from supplier to customer. The other is communications flow from customer back to supplier.

Taylor (2005) stated "Value Stream Maps are a very effective method for summarizing, presenting and communicating the key features of a process within an organization." LM is most frequently associated with the elimination of seven important wastes to ameliorate the effects of variability in supply, processing time or demand (Shah and Ward, 2007). Liker and Wu (2000) defined it as a philosophy of manufacturing that focusses on delivering the highest quality product on time and at the lowest cost. Jones and Womack (2000) defined it as the systematic removal of waste by all members of the organization from all areas of the value stream. Briefly, it is called lean as it uses less, or the minimum, of everything required to produce a product or perform a service (Lian and Van Landeghem, 2007).

Grewal (2008) used VSM techniques as lean implementation initiatives in small bicycle manufacturing company and claimed 33.18 percent reduction in cycle time, 81.5 percent reduction in change over time, 81.4 percent reduction in lead time and 1.41 percent reduction in value-added time.

Singh and Sharma (2009) implemented VSM approach in an Indian manufacturing organization and witnessed 92.58 percent reduction in lead time, 2.17 percent reduction in processing time, 97.1 percent reduction in WIP and 26.08 percent reduction in manpower requirement. Chowdary and George (2011) conducted a case study in a pharmaceutical company using VSM approach. The methodology assisted the case company in reducing lead times, cycle times and WIP inventory in the manufacturing process. The organization was able to reduce the storage area and production staff by 38 percent 50 percent, respectively.

Gurumurthy and Kodali (2011) presented an application of VSM with simulation during the design of lean manufacturing systems using a case study of an organization. Simulation studies were carried out for different scenarios such as "before LM" (current state VSM) and "after LM" (future state VSM). It was found that the case organization can achieve significant improvement in performance and can meet the increasing demand without any additional resources.

Majority of researchers have done the research on implementation of LM tools in large organizations. But in most of the nations, small and medium enterprises (SMEs) are the lifeblood of modern economies. Almost 90 percent SMEs in most countries are the driving forces behind a large number of innovations to the growth of national economy. The need for organizations to remain competitive and produce high-quality products is important not only at organizational level but also at global level. Hence, there is a need to implement such latest tools in SMEs to improve its competitiveness. In a nutshell, LM can be best defined as an approach to deliver the up-most value to the customer by eliminating waste through process and human design elements (Wong *et al.*, 2009).

## 3. Case study

A case study has been carried in a leading auto-parts manufacturing unit, located near Ludhiana, Punjab, India using VSM, having annual turnover approximately Rs. 15 million ($0.33 million). This organization was started in 1999 and is an ISO certified company. The company employs 300 personnel including workers, supervisors, engineers and also top management. The company was using traditional manufacturing concepts before applying lean concepts. The following procedure is adopted for this case study:

(1) selection of critical product family;

(2) preparation of current state map;

- documentation of customer information;
- establish process flow;
- data collection (cycle time, available time, in-process inventory, etc.);
- documentation of supplier information;

- establish information flow; and
- quantify production lead time and processing time.

(3) analysis of current state map;

(4) preparation of future state map;

- implementation of few new processes;
- calculate TAKT time; and
- develop continuous flow wherever possible; and

(5) analysis of the results.

The company is manufacturing ten different categories of products in the shop. Data have been collected for all the product families and the most critical product families, i.e. Weldon ball end and replacement ball were selected on the basis of the lead time of both the products was very much as compared to other products quantity to be produced were high and in-process inventory was also high to meet customer's demands and delivery schedule as shown in Figure 1.

Because of traditional manufacturing set up, in-process inventory was very high. The other reason for selection of both these products is the reduction of manufacturing days by the customer. Previously the manufacturing days were ten and shipping days were 35 (by sea), i.e. products reached at the customer's end within 45 days after receiving the order. In case of failure in meeting the delivery date, either the manufacturing organization will deliver the products by air instead of delivering by sea or otherwise the order will be treated as canceled.

*3.1 Preparation of VSM*

Current state map is prepared by taking the data from shop floor of the selected shop and also by consulting the foremen, operators, etc. The marketing department receives the information from customer and forecasts the exact demand. Marketing department sends this information to the production planning and control (PPC) department which further sends it to material requirement planning (MRP) department and supervisors, so that they can plan their GANTT charts accordingly. VSM is different than conventional recording approaches as it helps in visualization station cycle times, inventory buffers at intermediate stations, uptime or utilization of resources and the information flow in the given area. It captures the entire transformation from raw

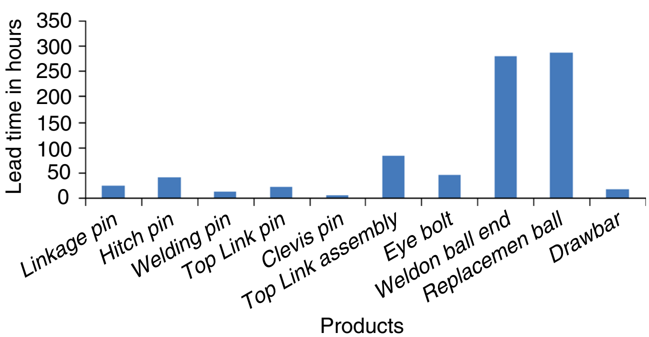


**Figure 1.** Comparison of lead time of various products

material to the reach of finished goods. This takes care of both value-added and non-value added activities. This is purely a pencil and paper work using icons for various agencies to visualize the flow of material and information as a product advances. Before mapping, one should be very clear about the lean management principles which form the backbone of VSM. 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 (Rother and Shook, 1999; Seth and Gupta, 2005). The major steps involved in mapping are as follows:

- An A3 size (or $11 \times 17$ inch) ledger size paper is taken and icons are drawn representing customer, supplier and production control with sufficient space in between them.
- Entries are made to prepare a data box below the icons to capture the monthly/daily requirements of each product along with number of containers and KANBAN required in unit time.
- Shipping and receiving data are entered along with the icons for the truck using direction arrows for the movement.
- Then manufacturing/assembly operations are drawn along the bottom of the map, with the most upstream process on the left and most downstream process on the right.
- This follows the entry of process attributes like uptime, changeover, etc. in proper units. It is essential to capture information flow both electronic and manual. For this communication, arrows are drawn between the parties concerned.
- Next inventory icons are drawn along with the quantities, in places where the inventory is stored between processes.

If a process is producing to a schedule independent of the downstream process this indicates that push is being practiced. In this way, the mechanism serves as a starting point to help management, engineers, suppliers and customers to recognize waste and its sources. Taking a value stream perspective means working on the big picture and improving the whole not just individual processes. Concepts of value stream provide both a picture of the current state of affairs as well as a guide about the gap areas. Thus it helps in visualizing how things would work when some improvements or changes are incorporated.

*3.2 Current state map of replacement ball*

Replacement ball is a tractor linkage part which is used mostly in linkage assembly; it is mounted on the rare side of the tractor and used to link the various parts. Its length can be adjustable from 230 to 930 mm. The demand per month of replacement ball is 15,000 pieces; effective numbers of working days are 25 per month. Number of shifts per day is two and working hours per shift are 12. Available working time per day in minutes is 1,440. TAKT time comes out to be is 144 seconds:

$$
\begin{aligned}
\text{TAKT time} &= \text{Available work time per shift/} \\
&\quad \text{Customer demand per shift} \\
&= 12 \times 60 \times 60/300 = 144\,\text{seconds}
\end{aligned}
$$

The demand comes from the customers (overseas mostly from European countries) to marketing department through some electronic media, then marketing department send this requirement to PPC department. Then PPC department analyses the products and make the material requirement planning and send the material requirement to suppliers by manually or by some electronic media. In present case, the suppliers take ten days to deliver the material, then material moves from raw material cutting department to finish product through number of processes like cutting, forging, drilling, computer numerical control (CNC) machining, etc. Details regarding inventory, cycle time, lead time, up time and number of shifts are shown in VSM. Current state map is shown in Figure 2.

After studying the current state map, it has been obtained that the maximum demand per month of replacement ball is 15,000 pieces. Actual cycle time of the replacement ball is 922 seconds; total in-process inventory is 1,150 pieces and maximum in-process inventory 750 pieces is at heat treatment process alone. And the lead time of the product is 289 hours. Second mostly the contractual labor is working in the organization. Third numbers of simultaneous families of products are in process. Since, the contractual labor is working; their labor rates are set by the management according to the type of the operation and quantity of the product to be manufactured. If the quantity of the product is more then the price of its operation will be less and if the quantity is less then the price will be more, i.e. number of units of product they operate in a day. So the operator is not worried about the type of the product. That is why the cycle time, work in-process inventory and production lead time are very high.

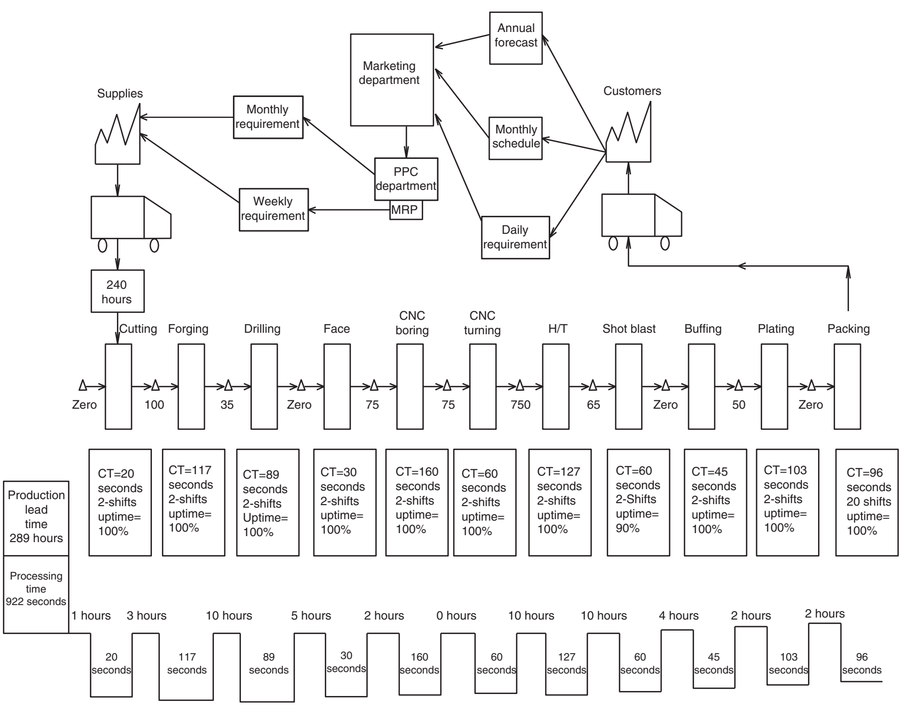


**Figure 2.**
Current state map of replacement ball

*3.3 Future state map of replacement ball*

After analyzing the current state map of replacement ball it has been found out that material arrangement is wasting much time than other processes. Almost ten days are required for the procurement of raw material only and after that time is being wasted at the processes for cutting and forging. It has been observed that the forging of this product is readily available in the market because there are many vendors who are producing same goods for other tractor linkage part industries. So, first step is to remove the cutting and forging operations by procuring directly the forging of these products. Second step is to remove the CNC boring operation by broaching operation. Also double heating furnace should be used to reduce the inventory of 750 units at heat treatment operations because that the demand is continuous. Withdrawal KANBAN should also flow from planning department to dispatch department. The KANBAN system brought the necessary schedule and delivery discipline. It has been observed that these products are readily available in the market as soon as the demand raises the forging procurement takes less than two days to provide that material to the machines. Thus it will help in reducing raw material inventory and also remove time-consuming processes to decrease the cycle time. It also helped in making whole supply chain very lean and flexible as shown in figure as shown in Figure 3.

Comparison of cycle times with the TAKT time of both current and future states of replacement ball has been shown in Figure 4.

Great changes were found after implementing the proposed changes. Like in-process inventory was reduced from 1,150 to 210. The lead time was reduced from 289 to 71 hours and cycle time was reduced from 922 to 640 seconds. Table I show that CNC boring is 160 seconds and it has been replaced with broaching operation, i.e. cycle time reduced to 30 seconds.

*3.4 Current state map of Weldon ball end*

Weldon ball end is also a tractor linkage part which is used in linkage assembly as explained earlier. Linkage assemblies are of two types, i.e. top link assembly and lower link assembly. Lower link assembly is mounted on the rare side of the tractor with Weldon ball ends welded on both sides of the strip. Mostly both the Weldon ends welded on the strip are of same size but sometimes these may be different according to the requirement of the next linkage part which is yet to link with the lower link assembly. Two lower link assemblies are mounted on the rare side of the tractor; it means four Weldon ball ends are required on one tractor. These are used to link the drawbar with the tractor on one side and on the other side these are linked with linkage pins.

The demand of Weldon ball end per month is 15,000 pieces; effective numbers of working days are 25 per month; number of shifts per day is two and working hours per shift are 12. Available working time per day in minutes is 1,440. TAKT time comes out to be is 144 seconds. Current state map is shown in Figure 5. Similar procedure has been used for this product also as explained above in the current state map of replacement ball. After receiving the order from the PPC department, MRP department orders the raw material to various suppliers. The time taken to supply the material to company after which production department starts the scheduled operations, i.e. converting raw material to finished goods is ten days. Details regarding inventory, cycle time, lead time, up time and number of shifts are shown in VSM.

After studying the current state map, it has been observed that the maximum demand per month demand of Weldon ball end is 15,000 pieces per month.

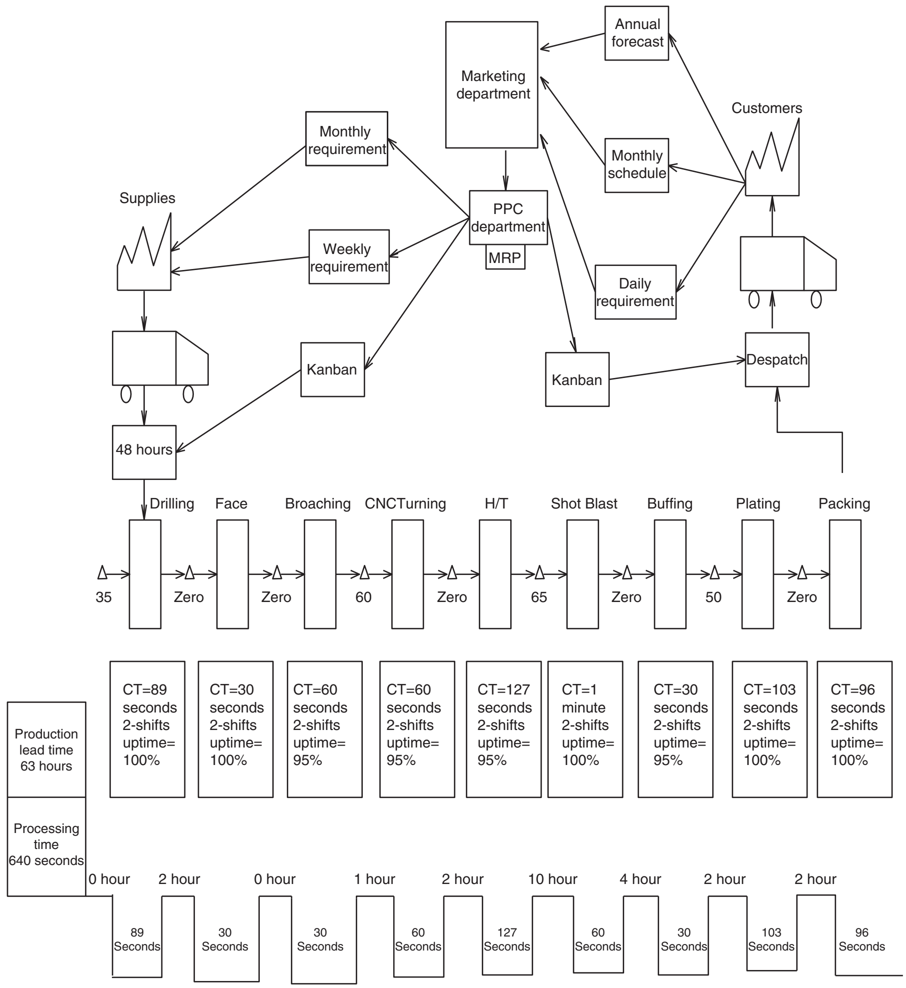


**Figure 3.**
Future state map of replacement ball

After studying, it was found out that cycle time of Weldon ball end is 1,066 seconds, total in-process inventory is 1,720 pieces, maximum in-process inventory, i.e. 1,000 pieces at stress relieving process and the production lead time comes out to be is 282 hours. Comparison of TAKT time with station cycle time is shown in Figure 6.

*3.5 Future state map of Weldon ball end*

Lean production system has been implemented, i.e. nothing is to be produced until it is needed. After procuring the goods, single minute exchange die method has been initiated in coining and ball clamping process. After analyzing the cycle times of various operations (like rough and final boring) were quite high as compared with that of TAKT time. The rough boring and final boring operations has been done on the simple lathes which were having copy turning attachments. So these operations were replaced by drilling and CNC boring, respectively. Moreover, on lathe machines the tool

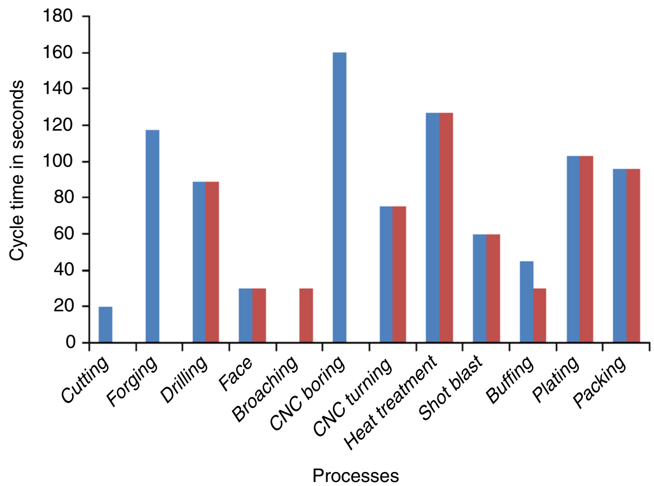


**Figure 4.**
Comparison of cycle time of current and future states for replacement ball

**Table I.**
Current and future states of replacement ball

| Processes | Cycle time (in seconds) Current | Future | In-process inventory (number) Current | Future | Production lead time (in hours) Current | Future |
|---|---|---|---|---|---|---|
| Material arrangement | | | 0 | | 240 | |
| Forging arrangement | 0 | 0 | | 0 | | 48 |
| Cutting | 20 | 0 | 0 | | 1 | |
| Forging | 117 | 0 | 100 | | 3 | |
| Drilling | 89 | 89 | 35 | 35 | 10 | 2 |
| Face | 30 | 30 | 0 | 0 | 5 | 0 |
| Broaching | | 30 | | | | 0 |
| CNC boring | 160 | | 75 | 0 | 2 | |
| CNC turning | 75 | 75 | 75 | 60 | 0 | 1 |
| Heat treatment | 127 | 127 | 750 | 0 | 10 | 2 |
| Shot blast | 60 | 60 | 65 | 65 | 10 | 10 |
| Buffing | 45 | 30 | 0 | 0 | 4 | 4 |
| Plating | 103 | 103 | 50 | 50 | 2 | 2 |
| Packing | 96 | 96 | 0 | 0 | 2 | 2 |
| Total | 922 | 640 | 1,150 | 210 | 289 | 71 |
| Percentage reduction | 69.41 | | 18.26 | | 24.57 | |

wear was very high and surface finish was also not very fine. Work instruction sheets have been introduced; daily production and rejection reports have been checked by the concerned engineer to ensure its daily production run. Thus it will help in reducing raw material inventory and also eliminating time consuming processes to assist in decreasing the cycle time as shown in Figure 7.

After implementing VSM, the cycle time has been reduced to 553 seconds instead of 1,066 seconds, in-process inventory was reduced to 370 units from 1,720 units and production lead time now is 73 hours. Earlier, it was 282 hours. Replacement of rough boring operation with CNC boring has reduced cycle times from 300 to 117 seconds as depicted in Table II.

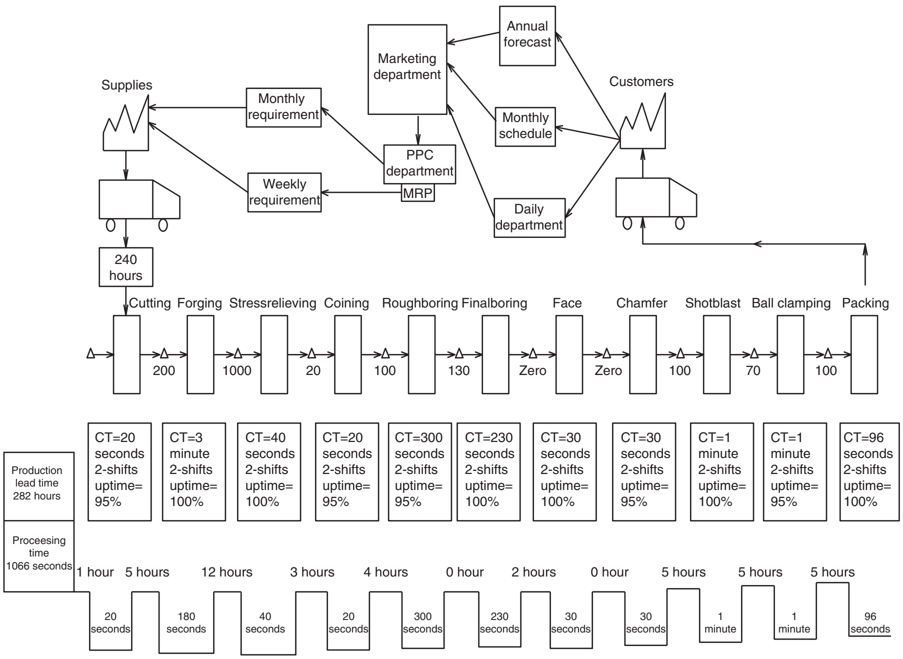


**Figure 5.**
Current state map of Weldon ball end

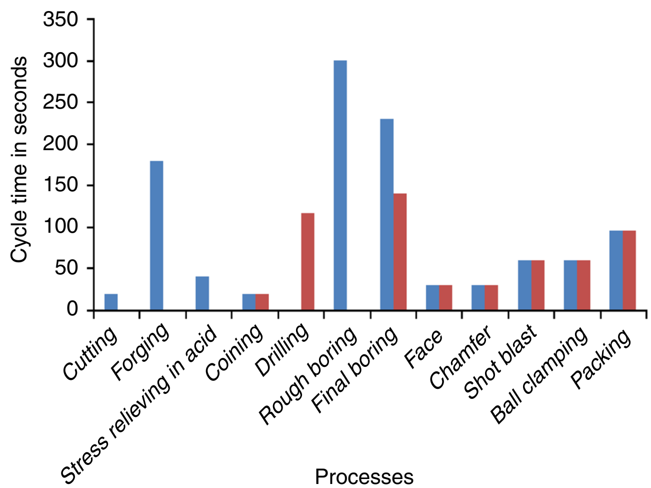


**Figure 6.**
Comparison of cycle time of current and future states for Weldon ball end

## 4. Conclusions

Most of the organizations are very keen to adopt latest techniques, namely VSM. It is a very powerful tool to highlight the process inefficiencies and improvement areas. In this case study, it has been illustrated with the help of VSM technique. Current state map and future state map have been prepared and analyzed to highlight the benefits of a lean system in a small company. In replacement ball, there is 69.41 percent reduction in cycle time, 18.26 percent reduction in work in process inventory and 24.56 percent

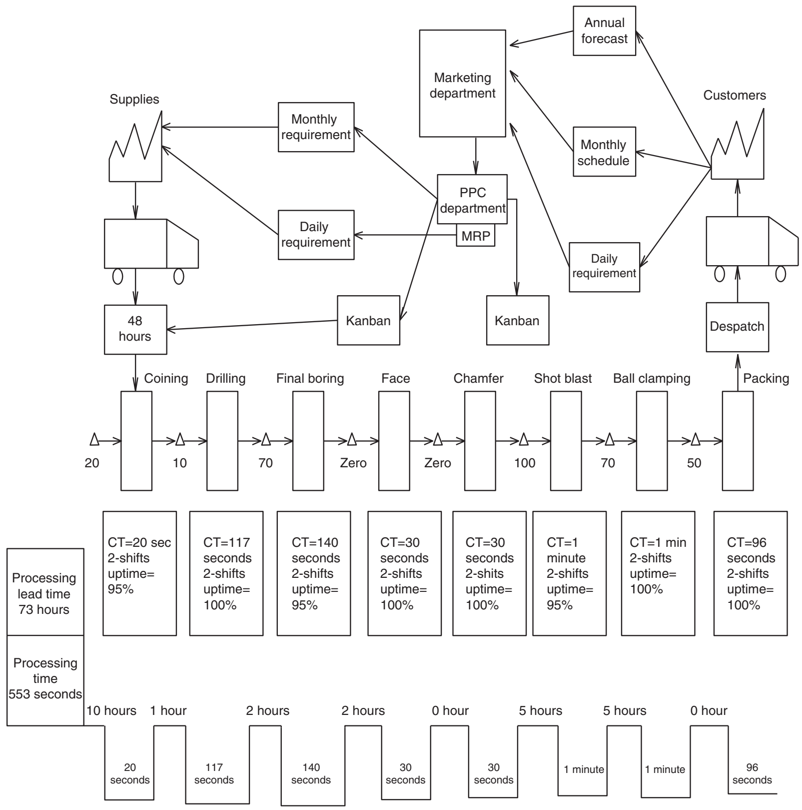


**Figure 7.**
Future state map of Weldon ball end

**Table II.**
Current and future state of Weldon ball end

| Processes | Cycle time (in seconds) Current | Cycle time (in seconds) Future | In-process inventory (number) Current | In-process inventory (number) Future | Production lead time (in hours) Current | Production lead time (in hours) Future |
|---|---|---|---|---|---|---|
| Material arrangement | | | 0 | | 240 | |
| Forging arrangement | | | | 0 | | 48 |
| Cutting | 20 | | 0 | | 1 | |
| Forging | 180 | | 200 | | 5 | |
| Stress relieving in acid | 40 | | 1,000 | | 12 | |
| Coining | 20 | 20 | 20 | 20 | 3 | 10 |
| Drilling | | 117 | | 10 | | 1 |
| Rough Boring | 300 | | 100 | | 4 | |
| Final boring | 230 | 140 | 130 | 70 | 0 | 2 |
| Face | 30 | 30 | 0 | 0 | 2 | 2 |
| Chamfer | 30 | 30 | 0 | 0 | 0 | 0 |
| Shot blast | 60 | 60 | 100 | 100 | 5 | 5 |
| Ball clamping | 60 | 60 | 70 | 70 | 5 | 5 |
| Packing | 96 | 96 | 100 | 100 | 5 | 0 |
| Total | 1,066 | 553 | 1,720 | 370 | 282 | 73 |
| Percentage reduction | 51.88 | | 21.51 | | 25.89 | |

reduction in production lead times. In Weldon ball end, there is 51.87 percent reduction in cycle time, 21.51 percent reduction in work in process inventory, 25.88 percent reduction in lead time after future state map application.

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