Lean Manufacturing Implementation Using Value Stream Mapping: A Case study of Pumps Manufacturing Company

Santosh B. Dighe[1], Abhay Kakirde[2]

[1]M.E. Dissertation, Department of Mechanical Engineering, Truba College of Engineering & Technology, Indore (M.P.), India

[2]Asst. Professor of the Department of Mechanical Engineering, Truba College of Engineering & Technology, Indore (M.P.), India

Abstract: ***Lean manufacturing refers to a manufacturing improvement process based on the fundamental goal of Toyota production system (TPS). That is, to minimize or eliminate waste while maximizing production flow. Many manufacturing organizations realize the importance of practicing lean techniques. A value stream includes all the operations and processes to transform raw materials into finished goods or services, including non-value adding activities. Value stream mapping is a lean manufacturing tool to plan a production process involving lean initiatives through systematic data capture and analysis. It is a proven process for planning the improvements that will allow companies to develop lean practices. This tool has been used to document current lead time, inventory levels and cycle times to determine the ratio of value added to total lead time of the product line being analysed. The first step of value stream mapping is to create a current state map to make a picture of the production flow and understand the company's current cycle times, process communications, and machine equipment capacity. This provides the information needed to produce a future state map by creating a vision of an improved value flow. The goal is to identify and eliminate the waste, which is any activity that does not add value to the final product, in the production process.***

Keywords*:* TPS, VSM, JIT, Takt Time, Cycle Time, Lead Time, WIP, FGI

1. Introduction

In the past, the rule of traditional business in the manufacturing industry was dictated by a high volume of products at low costs. Today, lean manufacturing has been a great interest for manufacturers not only in India but the whole world. It is called "Lean" because this technology, or a process, helps manufacturers to produce more with less time, inventory, capital and fewer resources. The objective of this paper is to use a case based approach to demonstrate how lean manufacturing principles when used appropriately, can help a make-to stock production system eliminate waste , maintain better inventory control and reduce manufacturing lead-time. A pump manufacturing unit is used to illustrate this approach. The unit manufactures a variety of centrifugal pumps for agriculture, domestic and industrial applications. Out of the four pump families being manufactured, namely Three Phase Monoblock Pump has been taken up for the detailed analysis. The components of the pumps namely motor body, end shields, mounting casing, delivery casing, impeller, are made from grey cast iron castings produced in the company's own foundry and also received from vendors. Shafts are made by machining steel bars received from the suppliers. Various machining and assembly operations are also carried out within the factory.

In this work, various operations have been carefully observed and the records of production have been analysed to find out root cause of various types of wastes at different stages. Having determined the type and quantum of waste at every stage it was ascertained as to how far the company is from the concept of lean manufacturing. A root cause analysis of various types of waste has been carried out with an aim to design a strategy for implementation of lean manufacturing. Subsequently an action plan has been developed for step wise implementation of lean manufacturing which is primarily based on removing the root causes of various wastes. The company wants to change from the way the product are being produced and flowed through the factory so that the company could become lean within their manufacturing environment. The company was experiencing large amount of work in process and finished goods inventories. By recognizing the benefits of lean manufacturing using a pull system as opposed to a push system, the company made the decision to implement lean principles and promoting a pull system. The work focuses on the application of value stream mapping in lean transformation.

2. Literature Review

The authors of this paper have discussed the factors responsible for lean practices in Indian industries. The authors investigated the Lean Manufacturing practices adopted by different industries in Maharashtra, India. The findings from the research show that Lean manufacturing system is regarded as intended direction, rather than a steady state. For successful organizational change towards lean organization, the critical factors are strong employee involvement, effective communication, and top management support [1].

Authors in their paper have given an insight into adoption of lean manufacturing in the electrical and electronics industry in Malaysia [2]. They explored14 key areas of lean manufacturing namely, scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, and tools and techniques as suggested by authors [3].

This research investigates the critical success factors (CSFs) involved in implementing lean tools and ERP systems with the aim of understanding how these CSFs have changed over time and, so currently, enterprises are struggling hard to maintain competitiveness in the market; therefore, lean tools and ERP systems have been receiving great attention, to assist enterprises to survive combination of lean tools and ERP systems will reduce overall waste in business processes and link the entire company department together to improve the communication and availability of real information flow within and between departments[4]

This paper provides an insight in the various ways IT supports current developments in lean production. The Toyota Production System has shown that IT can provide support to the decisions of planners and employees without completely taking over control. Recent developments in pull system design for make-to-order and engineer-to-order situations, such as ConWIP and POLCA, involve advanced IT in a similar way.

And a recent publication on the ‘‘e-Kanban’’ system that Toyota Motor Company nowadays uses for supply chain control shows how modern IT and intelligent algorithms are involved for adaptive control of the system [5].

In this paper authors demonstrate how the value stream mapping (VSM) suite of tools can be used to map the current state of a production line and design a desired future state. , they provide a roadmap for how VSM can provide necessary information for analysis of equipment replacement decision problems encountered in lean manufacturing implementation. A large integrated steel mill is used to illustrate the approach followed [6].

Authors describe a case where lean principles were adapted for the process sector for application at a large integrated steel mill. Value stream mapping was the main tool used to identify the opportunities for various lean techniques [7]. Research papers [8], [9], [10] discuss the applications of VSM technique in different industries.

3. Objective

The research objectives have been defined as follows:

- To understand the ‘current state’ manufacturing process for the pump family selected.
- To identify the key areas of waste, problem and opportunity across the process.
- To develop a ‘future state vision’ of process..
- To reduce waste (NVA).
- To reduce inventory.
- To reduce Production Lead-time.

4. Methodology

The VSM methodology adopted in this work is a systems approach, where the “whole” is not equal to the sum of its components, as their relations are of importance as well. The systems approach will help to provide a holistic view during the project. A combination of case study and action research has been used as the research method. Initially the research will start off with a case study to build a thorough understanding of the business and processes. After this has been achieved the focus will be altered to improving the process while observing it. This means that the research method will be changed into action research. The important steps to getting started with value stream mapping process which have been followed in this work is shown in Figure 5.1

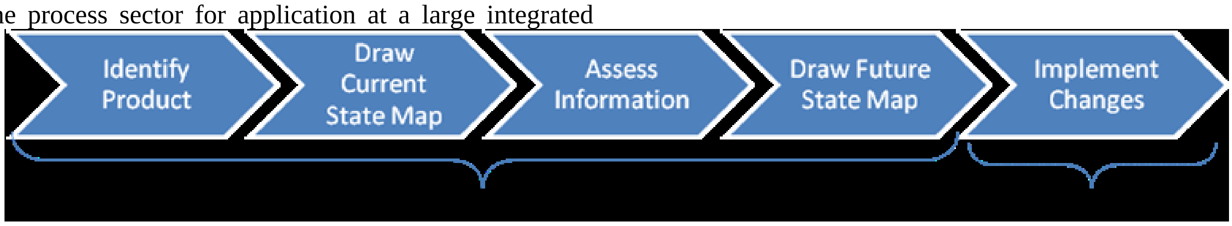

Figure 4.1: Lean Implementation methodology

In order to accomplish these objectives we have applied the following strategies:

- Obtained information from various employees
- Conducted time studies
- Observed processes during different times of the day, on different days of the week

5. Value Stream Mapping

A value stream map can be defined as all the steps – both value added and non value added- required to take a product from its raw materials state into the waiting arms of a happy customer. The first is to identify the product family which we consider as lean candidate.

5.1 Selection of Product

The tool used for this purpose is a Product Quantity/ Product Value matris.

Table 5.1: Product Quantity / Value Matrix

Product Family	*Quantity*
A	78686
B	38449
C	33129
D	70
E	20845
F	1749
G	11904
Total	184832

Product Family	*Sales Value (Rs Millions)*
A	448.96
B	746.47
C	294.98
D	0.38
E	285.32
F	30.54
G	180.54
Total	1987.19

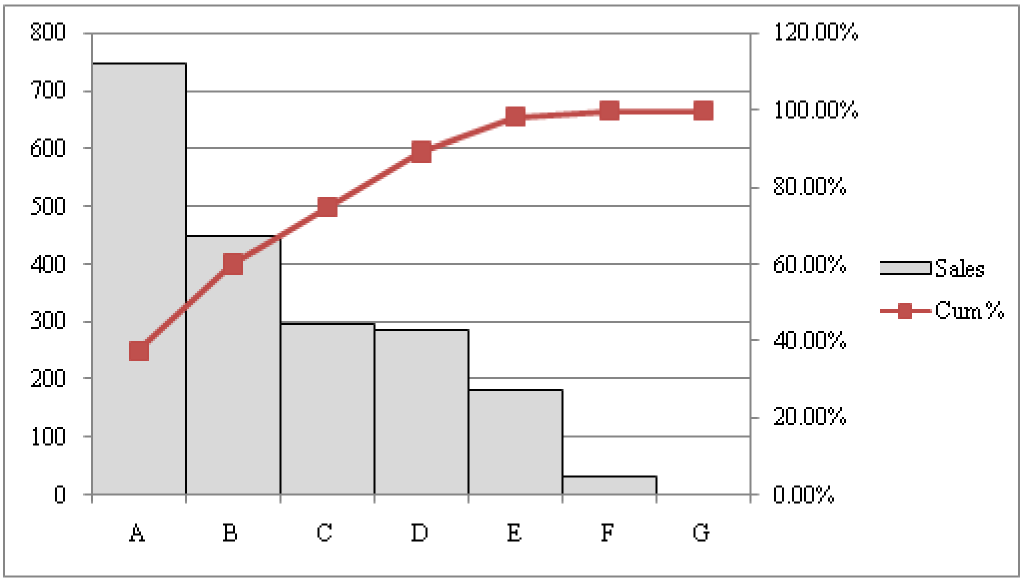

Figure 5.1: Pareto chart for Product wise volume of production

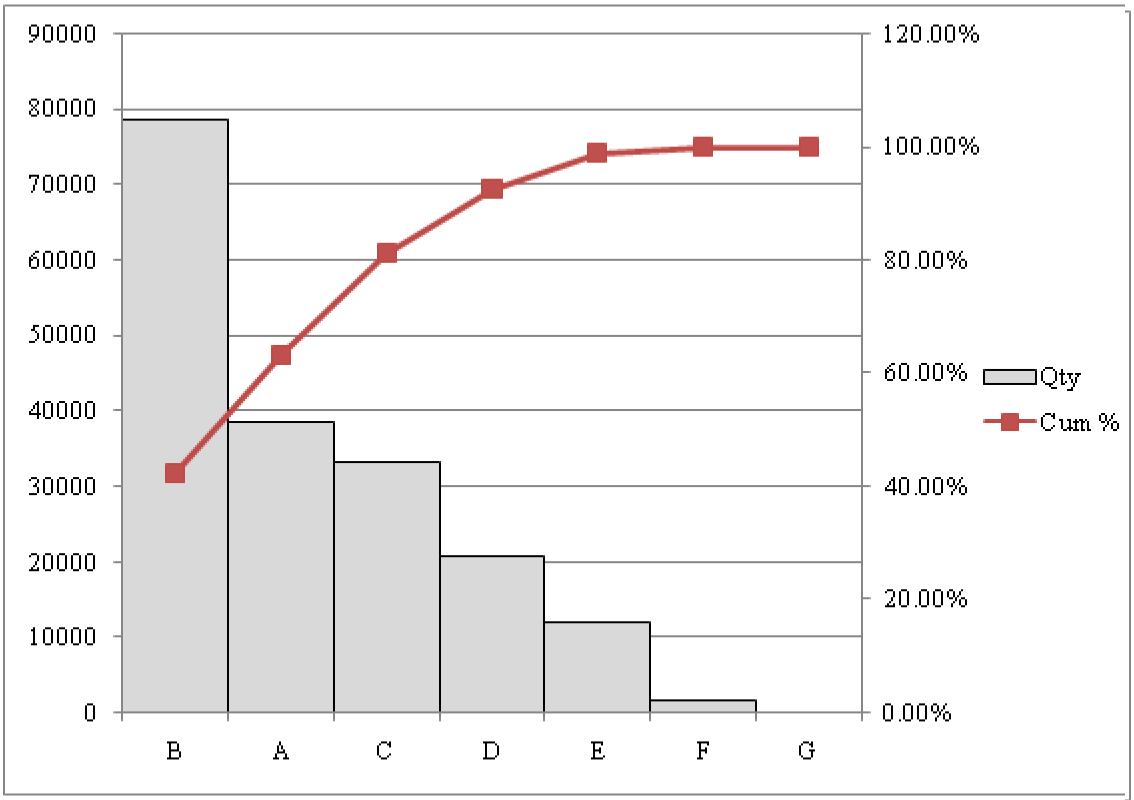

Figure 5.2: Pareto chart for Product wise Sales

5.2 Pareto Analysis and Result

The pump family, A, is the first place "winner" based on units shipped. However, the first place "winner" based on sales value in rupees is "B"(Three Phase Monoblock) pumps family. After discussions with management the B Pump has been selected for improvement under this study.

5.3 Process Description

Major components of a pump are Impeller, Delivery Casing, Mounting Casing, Motor Body, Stator, Rotor and Shafts etc. While Stator and Rotor are bought out components others are manufactured in-house. Within the factory premises there is a Foundry producing Grey Cast Iron castings. It has a pattern shop, a core shop and a Fettling shop with Materials testing laboratory. Raw materials and standard items e.g. Bearings, Seals, Nuts and Bolts etc. are received from suppliers and stored in a central store. Castings are stored in Casting Yard near foundry. These are moved to CED (Cathode Electronic Deposition) Plant where pump parts (e.g. Impellers, Delivery casings etc) are coated with a protective layer to prevent rusting. The processes involve are – washing, degreasing, phosphating, coating and baking. Components are machined in machine-shop and delivered to Assembly-shop for pump assembly. Pumps are then tested, painted, packed and delivered to a Finished Goods Store.

5.4 Assembly Operations

- Washing and CED
- Ball Bearing pressing
- Mounting casing & rotor shaft assembly
- Motor testing and connection
- Gland cutting and impeller assembly
- Accessories fitting and loading on conveyor
- Painting
- Packing

A summary of data for each process of pump manufacturing is given in the Table 5.1

Table 5.1: Process Data Summary

Process	*Cycle time (in sec)*	*Lot size*	*Head count*	*Shifts*	*WIP*	*C/O*	*D/T*
1. Washing & CED	18	20	4	2	2.5H	10	0.7%
2. Ball Bearing pressing	54	5	0.5	3	3.2H	--	-
3. Mounting casing Rotor Shaft Assembly	381	5	1.5	3	1.3H		
4. Motor testing and connection	271	5	1	3	3.2H		
5. Gland cutting and Impeller assembly	175	5	1	3	4.2H		
6. Delivery casing assembly	214	1	1	3	7.2H		
7. Accessories fitting and loading on conveyor	235	5	2	3	7.2H		
8. Painting	83	1	1	3	0		
9. Packing	535	5	4	3	1.6H		

5.5 Creating Current State VSM

Mapping the value stream always start with the customer demand. To create the Current State map the following steps are followed:

Step I- Understand Customer Demand:
In this study Customer demand is 100 pcs/shift or 300 pcs/day assuming 3 shifts.

Step II- Calculate Takt Time
Takt time = Daily Available Production (sec) / Daily customer demand = 77640/300 = 258.8
Takt Time for this process is 258.8 secs

Step III- Mapping the Process Flow
This step involves various processes which are in sequence to complete product manufacturing and calculation of cycle time, change over time and up time for each. In this research nine processes are given to complete the products which are discussed earlier.

Step IV- Map the Material Flow
The flow of material from the raw material to finished good is given by supplier to customer.

Step V- Map Information Flow
The information flow is also incorporated to provide demand information, which is an essential parameter for determining the process in production system. Various data regarding cycle time(C/T) change over time (C/O), down time (DT), Takt-time (TT) etc.

Step VI- Calculate Total Product Cycle Time
After both material and information flows have been mapped, a time-line is displayed at the bottom of the map showing the processing time for each operation and the transfer delay between operations. The time-line is used to identify the value-adding steps, as well as wastes. PLT for our process is 54 days.

Step VII- Detail Off-line Activities:
Activities like placing of order, supply of material, daily schedule, monthly forecast etc involved are well executed by transportation, supplier icons and information flow lines.

Step VIII- Identify Opportunities For Improvement:
Opportunities are identified and also to further improve throughput rate and to draw a future state map which shows changes in the process.

5.6 Analysis of Current state VSM

We analysed current state map and following gaps were identified for improvement:

- Fire fighting to meet market demand at short notices.
- High lead time for die cast rotors and stator windings
- High cycle time for rotor shaft machining
- Multiple material movements for Delivery casing and Impeller causing high inventory
- Variable stock in Finished Goods store (FGS)
- Extra processing of impeller increasing lead time
- High inventory at input and output of CED

- Cycle time improvement for assembly and packing
- Reduction of stator rejection at mandrel operation
- Engagement of operators is not balanced

5.7 Creating Future State Map

To create future state map we gathered following information:

- Total VA = 0.55 Hrs
- Total NVA = 784.4 Hrs
- % VA = 0.07%
- Total Lead Time – 54 Days
- Total Distance – 5000 m
- Total Assembly Area – 432 sq.m
- Total HC/shift – 12 no
- O/P/HC/shift – 8 pcs
- Inventory – 33 Days
- Yield – 97.5%

Step I – Create a Cycle Time v/s Takt Time Graph
From the data collected and calculated during the creation of the current state map we are able to draw a cycle time v/s takt time graph as shown in Fig.6.1. This graph simply compares the individual cycle times to the overall takt time of the manufacturing process. This is an important step as it will help us make decisions as to how and what to improve in future steps.

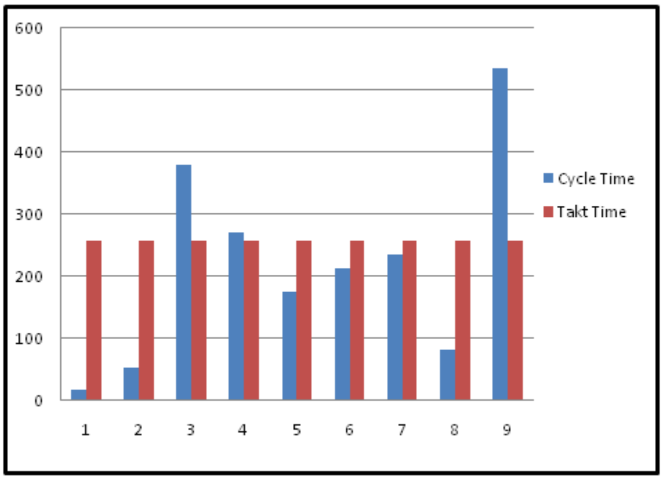

Figure 5.3: Bar Chart for Cycle Time V/S Takt Time

Step II – Single Piece Flow Model
Next, we must decide what type of production and distribution model we will develop. We have created Single Piece Flow model for our process.

Step III – Calculate Optimal workforce Size
Optimal no. of workers is equal to Total Cycle Time/ Takt Time i.e. 1836 sec/258.8 sec = 7
Optimal size for our process is 7 nos.

Step IV – Pull Process:
Anytime we build to supermarkets we must have a way of signalling when to produce and when not to produce. There are a variety of ways to accomplish this. The easiest way is to use Kanban. Market pull system with Kanban has been suggested between FGS and assembly line.

6. Results and Discussion

The results are shown in the form of current and future VSMs (refer Fig.6.1 and Fig6.2 respectively) and improvement is shown in the reduction of waste (NVA), inventory and lead time.

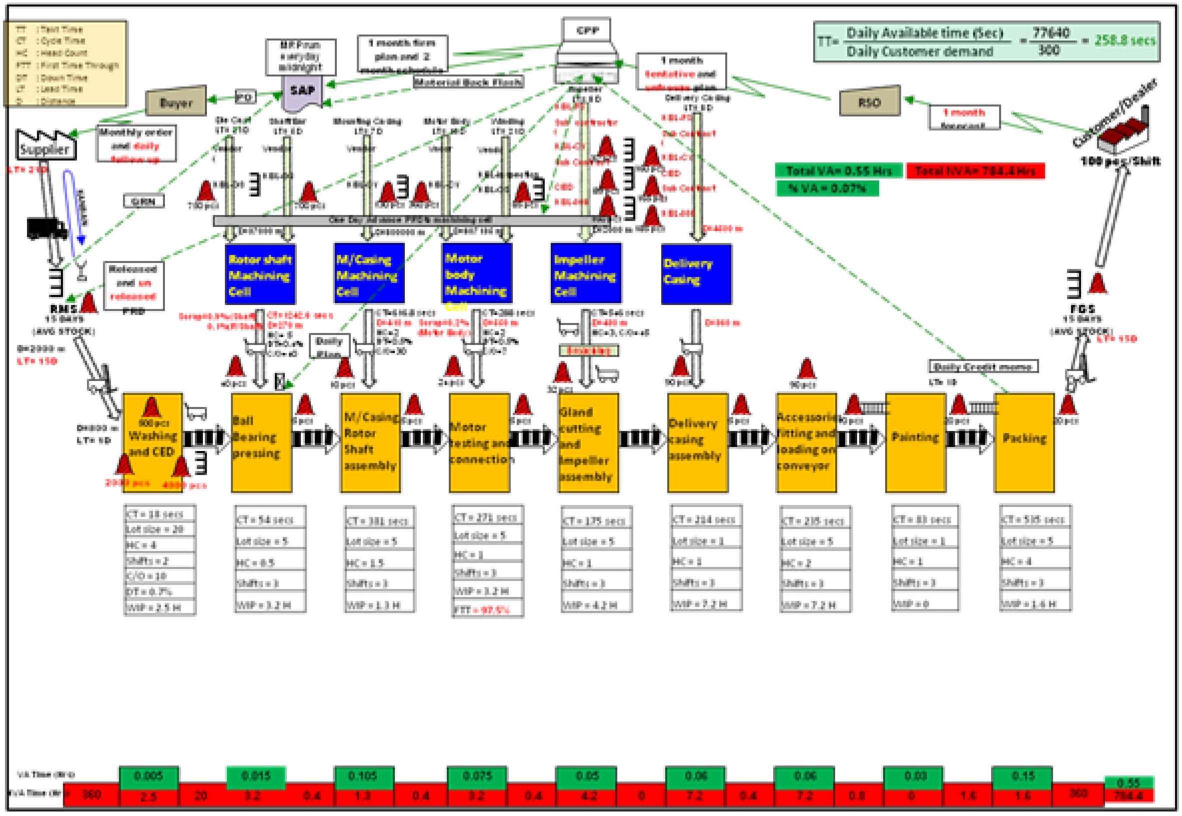

Fig.6.1 CURRENT STATE VSM FOR THREE PHASE MONOBLOC PUMP

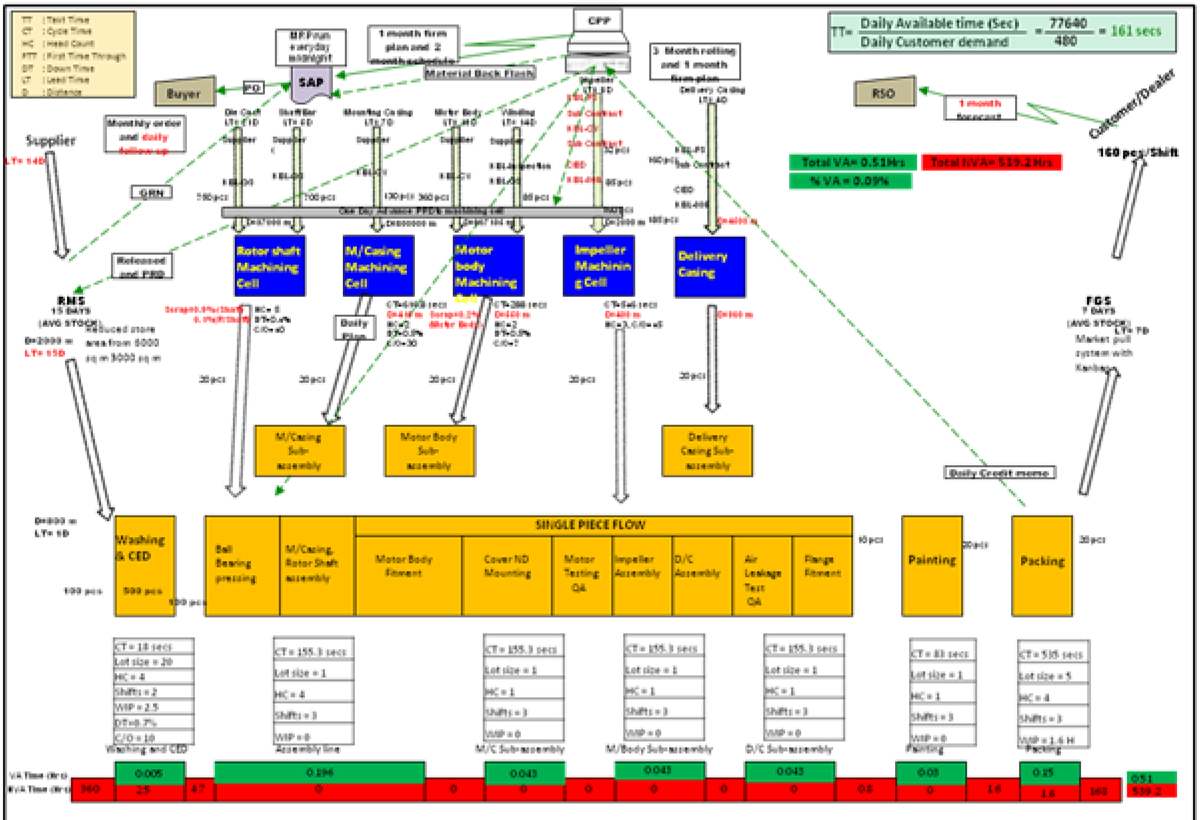

Fig.6.2 FUTURE STATE VSM FOR THREE PHASE MONOBLOC PUMP

7. Conclusions

The purpose of this study was to develop a value stream map for assembly process of motor, and pump parts. The goal has been to identify and eliminate waste which is any activity that does not add value to the final product in the assembly process. It is also aimed at reducing lead time and increasing throughput rate of parts.

The following are some of the salient conclusions that are drawn based on the present studies:

- It was observed from the current state map that the total lead time for the product is 54 days, Inventory is 33 days and value added time is 0.55 Hrs and %VA is 0.07%.
- The difference between lead time and processing time shows that there are lots of non value activities in the process flow which is in the form of waiting for parts, moving parts from one station to another, setting up time and inventories.
- The process turns from push to pull.
- Process lead time reduces to 36.5 days, Inventory reduces to 22.4 days
- Having the proper analysis tools is a key perquisite for making significant improvements to a manufacturing system. But implementation is more than a matter of being right. An effective manufacturing manager must pull together a coherent plan and nurture it to fruition.
- This requires (1) addressing the right problem and (2) convincing others that it needs to be solved. The first is a subject matter of systems analysis, while the second deals with the human element of manufacturing management.

8. Future Scope

The following points are suggested for future work:
- This research work is focused on lean implementation using VSM only. The research may further be explored in deployment of other lean tools namely 5S, Kaizen, TPM, SMED, Kanban etc.
- Using the background of this research, application of VSM may be extended to Foundry department of the pump manufacturing unit.

9. Acknowledgment

We would like to thank the management and staff of M/s XYZ Limited for the help and support provided in completing this study.

References

[1] Priti B. Khadse ,Avinash D.Sarode ,Renu Wasu “Lean Manufacturing in Indian Industries Review” ,International Journal of Latest Trends in Engineering and Technology (IJLTET) Vol. 3 Issue 1 pp 175-181,September 2013
[2] Yu Cheng Wong, Kuan Yew Wong, Anwar Ali. “A Study on Lean Manufacturing Implementation in the Malaysian Electrical and Electronics Industry**”,** European Journal of Scientific Research 1450-216X Vol.38 No.4 (2009), pp 521-535.
[3] Wong, Y.C., Wong, K.Y. and Ali, A., 2009. “Key practice areas of lean manufacturing”, Proceedings of the International Association of Computer Science and Information Technology Spring Conference (IACSIT-SC 2009), Singapore, pp. 267-271.
[4] Alaskari. O, et al, “Critical Successful Factors (CSFs) for Successful Implementation of Lean Tools and ERP Systems “Proceedings of the World Congress on Engineering, 2012 ,Vol III,WCE 2012, July 4 - 6, 2012, London, U.K.
[5] S. Kotani, Optimal method for changing the number of kanbans in the e-Kanban System and its applications, International Journal of Production Research 45 (24) (2008) 5789–58
[6] William G. Sullivan, Thomas N. McDonald, Eileen M. Van Aken, “Equipment replacement decisions and lean manufacturing” Robotics and Computer Integrated Manufacturing, Vol. 18 (2002), pp. 255–265
[7] Fawaz A. Abdulmaleka, Jayant Rajgopal “Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study” Int. J. Production Economics 107 (2007) 223–236
[8] Rahani AR, Muhammad al-Ashraf “”Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study, Procedia Engineering 41 (2012) 1727 – 1734, International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012
[9]] Soniya Parihar et al “Value Stream Mapping: A Case study of Assembly Process” International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 8, October – 2012
[10] J. Dinesh et al “Reduction of lead time using value stream mapping in pump manufacturing industry” Proceedings of the National Conference on Manufacturing Innovation Strategies & Appealing Advancements, April 19, 2013, PSG College of Technology, Coimbatore, India

Author Profile

Santosh B.Dighe is pursuing Master’s Degree in Production Engineering & Engineering Design from Truba Institute of Engineering & Technology, Indore (Affiliated to RGPV, Bhopal), India

Mr. Abhay Kakirde is a Assistant Professor in Mechanical Department of Truba Institute of Engineering & Technology, Indore, India.