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Value Stream Mapping: Literature Review And Implementation For An Assembly Line

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Abstract: *ean manufacturing initiative is being followed by various organizations in the recent years which mainly focus on improving the efficiency of operations by eliminating and reducing wastes. A major activity in the journey towards lean is the effective management of the flow of products and services through the series of the activities involved in providing value to the customer, known as the value stream mapping. Value steam mapping (VSM) is a lean manufacturing technique and it has emerged as the preferred way to support and implement the lean approach Grewal (Int J ManufTechnolManag 15:3–4, 2008); Singh and Sharma (J Measuring Business Excellence 13:58–68, 2009). VSM is different than conventional recording techniques, as it captures the information at individual stations about station cycle time, up time or utilization of resources, set-up time or change over time, work in process inventory, man power requirement and the information flow from raw material to finish goods. It covers both value adding as well as non-value-adding activities.*
This paper covers the review and classification of literature on VSM, as there is hardly any paper on literature review of VSM, so it will be very beneficiary for both academician and industry people. Applications of VSM are also presented by a practical implementation on an assembly process and reduction in cycle time, processing time, and work in process inventory and manpower requirement at individual stations in an assembly process of automobile industry located in Gurgaon (India).
Keywords: *Value stream mapping, lead time, Kanban, Inventory, Cycle time*

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I. Introduction

This Paper is a case study explaining about the successful implementation of lean manufacturing tools and techniques in the development and implementation of an assembly processes at the case industry plant.
In 1990 a book appeared by the title, The Machine that Changed the World, often referred to as the "MIT study", describes the principles of LP and opens new areas for leanness. Womack J.P et al. (1990). The concept of lean manufacturing was introduced in the Toyota production system and it was the first to use lean practices. Lean manufacturing enhances production processes and boosts the employee's job satisfaction Singh, Garg, Sharma,& Grewal (2010). Lean manufacturing believes the simple fact that customers will pay for the value of services they receive, but will not pay for mistakes Rawabdeh (2005). lean principles are capable of improving sustainability of an industry. Lean principles are aimed at waste reduction hence results in capital gain. In addition to this, sustainable benefits are also achieved the various tools and principles of lean. Some of the sustainable benefits from lean principles are reduction in material usage, energy consumption, hazardous waste, water usage, etc. The various sustainable benefits from the lean principles are shown in Table 1 (Fliedner 2008).

Table 1. Environmental benefit of lean principles

Lean principles/tools	Sustainable benefits
Pull approach	Reduction of work-in-process, elimination of potential waste from damaged products, lesser floor space utilization
Cellular manufacturing	Reduction in set-up times and change over time hence low energy and resource usage, reduction in defects
Value stream Mapping	Reduction in waste through fewer defects, less scraps, low energy usage, etc.
5S	Reduction in lighting requirements due to clean windows, leaks attended to immediately, reduced consumption of materials and chemicals
Total preventive maintenance	Less hazardous waste due to decreased spills and leaks, increased longevity of equipment
Six sigma	Fewer defects hence less waste, improvement in product durability and reliability hence increase in product lifespan
Pre-Production planning	Reduction of waste at design stage, usage of right sized equipment,

	reducing the complexities of production processes and product design
Kaizen	Elimination of hidden wastes and unwanted activities
Visual controls	Identification and elimination of unwanted entities hence less material usage and wastes
Lean supplier	networks Introduction of lean to existing suppliers would lead to better realization of environmental benefits
PoKaYoKe	Reduction in defects hence less waste, low energy usage, less scrap

Saurin and Ferreira (2009) have presented guidelines for assessing lean production impacts on working conditions either at a plant or a departmental level, which were tested on a harvester assembly line in Brazil. Narahari et al (1999) explored how the lead times can be reduced using scheduling, input control, load balancing and variability reduction. McDonald et al (2000) explained wasteful steps that have to be eliminated and flow can be introduced in the remaining value-added processes. The concept of flow is to make parts ideally one piece at a time from raw materials to finished goods and to move them one by one to the next workstation with no waiting time in between. Pull is the notion of producing at the rate of the demand of the customer. Perfection is achieved when people within the organization realize that the continuous improvement process of eliminating waste and reducing mistakes while offering what the customer actually wants becomes possible. Khaswala et al (2001) explained the basic concepts of Value stream mapping and how to implement them in case of multiple flow value stream mapping that merge in case of a complex product. Abdulmalek and Rajagopal (2006) presented lean manufacturing principles being applied to a steel mill. The lean manufacturing tool of value stream mapping has been used to map the scenarios. The paper also described simulation models which were developed using lean manufacturing principles and also analyzed the possible benefits. Ward (2007) addressed the confusion and inconsistency associated with "lean manufacturing" concept to clarify the semantic confusion surrounding lean production by conducting an extensive literature review using a historical evolutionary perspective in tracing its main components. Rother (1990) described how Toyota manages continuous improvement, human ingenuity, through its improvement kata and coaching kata. He also explains why typical companies fail to understand the core of lean and make limited progress. The two metrics are the lead time and Percentage value added work. William et al (2011) presented the use of value stream mapping tool in identifying, quantifying and minimizing major wastes in a bread manufacturing set-up. The case study shows how the VSM tool was used to identify and reduce defects, unnecessary inventory, and motion.

Tapping et al (2000) wrote a book on value stream management system and how it simplifies the planning process for leanimplementation, ensuring quick deployment and greater success. Ron Moore (2002) wrote a book on selecting the rightmanufacturing improvement tools and showed how these tools can be implemented and supported. It also relates to one anotherand compares their strengths and weaknesses. It also provides an excellent review of the most popular improvement tools andstrategies - Lean Manufacturing, Kaizen etc. Salomon et al. (2007) used multiple decision making for supplier selection ofassembly line equipments in an automotive industry. Kull and Tallurai (2008) proposed a combination of analytical hierarchicalprocess and goal programming as a decision tool for supplier in the presence of risk measures and product life cycleconsiderations.

Value stream mapping is an enterprise improvement tool to help in visualizing the entire production process, representing both material and information flow. Defined value stream ascollection of all activities value added as well as non-value added that are required to bring a product or a group of products that use the same resources through the main flows, from rawmaterial to the end customers. Avery important part of the value stream mapping process is documenting the relationships between the manufacturing processes and the controls used to manage these processes, such as production scheduling and production information. Unlike most process mapping techniques that often, only document the basic product flow, value stream mapping also documents the flow of information within the system, where the materials are stored (raw materials and work in process, WIP) and what triggers the movement of material from one process to the next are key pieces of information. Value stream maps for determining the beliefs, behaviours, and competencies possessed by business leaders were described and with the help of current and future states map, the ineffectiveness of most senior managers as well as traditional leadership development programs were highlighted

It follows that value stream mapping has proven effective in many manufacturing organisations. Pavnaskar et al. (2003) argue that:

- In the use of VSM, the analysis of the initial situation is based on the acquisition and treatment ofnumerical data, and uses a graphical interface that makes it easier to see the relationship between materialand information flows.
- The systemic vision provided for each product family reflects manufacturing system inefficiencies. This isalso highlighted by Jones and Womack (2003).

- A common language can be provided for the team to unify lean concepts and techniques in a single body.This is also highlighted by Baker (2003).
- There is the possibility of VSM being the starting point of strategic plan improvement (Gregory 2003).

A number of researchers have provided aninsight on this aspect of manufacturing process engineering. They have reported that some of the limitations ofVSM include the following:

- Because most VSMs are 'paper-and-pencil-based', the accuracy level is limited, and the number of versionsthat can be handled is low (Braglia et al. 2006, Lian and Van Landeghem 2007).
- In complex manufacturing environments with multi-product flows, it is extremely difficult to map all theprocess routes (Duggan 2003, Braglia et al. 2006, Agyapong-Kodua et al. 2009).
- It is also not suitable for dynamic analysis (McDonald et al. 2002, Agyapong-Kodua et al. 2009).

Based on a review of existing literature on methodologies and tools for the redesign of manufacturing systems,Serrano et al. (2008), after evaluating the performance of VSM in manufacturing systems design, indicated that inbroad terms, 'flow diagram charts', 'structured systems', 'architectural systems', 'modelling and simulation software'are the four main tools currently deployed for manufacturing systems redesign and engineering.

Value Stream Mapping (VSM) is used to define and analyze the current state for a product value stream and design a future state focused on reducing waste, improving lead-time, and improving workflow.A value stream map provides a blueprint for implementing lean manufacturing concepts by illustrating how the flow of information and materials should operate. VSM is divided into two components: big picture mapping and detailed mapping. Rajenthirakumar and R.G. Shankar reported a noticeable reduction in cycle time and increase in cycle efficiency with an application of value stream mapping (VSM). The production flow was optimized thus minimizing several non-value added activities/times such as bottleneck time, waiting time, material handling time, etc. K. P. Paranitharan provide useful platform for research in implementation of lean tools in any manufacturing unit. Their results show a significant improvement in productivity, reduction of Production Lead Time and reduction in inventory. These can be achieved by creating flow by layout modification and balance to TAKT time

Problems in existing system

The following wastages were identified in the current system of an assemble process;

- High additional processing time.
- More number of workers.
- Consumes more resources.
- More inventory.
- More scrap and
- High Cycle time

II. VSM Methodology

Step 1: Gather Preliminary Information- Examples of the required information might include product mix, volume, sales, quality issues, etc.

Step 2: Create a Product Quantity Routing Analysis- This includes listing all of your customers and the products you supply for each.

Step 3: Sort Product Families by Process Sequence- Identify product families according to a similar process sequence. This will help with mapping through the flow of your operations.

Step 4: Create an Operations Flow Chart- Create a flow chart of all of the operations in your value stream.

Step 5: Walk the Shop Floor- The team needs to walk through the steps of your value stream where the work is being done, beginning to end. You will not be able to see wasted time or steps from the office.

Step 6: Collect the Data- Data such as time should be collected. Conduct time studies where applicable, and involve the operators; they can be the best source for information when the data is unavailable.

Step 7: Construct the VSM- On your sheet of paper (or whiteboard), construct the VSM using symbols to indicate what is happening at each process (refer to the symbols chart).

Step 8: Summarize the Data and Get the Big Picture-

As Chris Hoff points out, "When you have identified all the steps in your value stream and have filled in all the Data applicable to your VSM, it's time to put it all together. Remember, the point [is] to use your VSM to see where the value is being created and identify where wasteful activity occurs. In addition, looking at your VSM, take the list of Kaizen opportunities you identified in this process and begin prioritizing them by the level of impact an improvement will make to the flow of your value stream. This will give your team an organized plan of action from which to start making improvements to your value stream."

III. Case study

A case study was conducted at an automotive industry, in the assembly line. The automotive industry is a leading producer of Speedometers. The production line was properly examined and a major product contributing to highest non value added time was selected for the case study. All the primary and secondary data was collected for further study. Both, value added and non-value added time along with the lead time of the product was calculated. The Bottleneck operations were identified.

Case study demonstrates the application of VSM in XYZ Manufacturing Industry located in Patiala, Punjab, India. It is a small manufacturing industry and manufactures the various components used for maintenance of railway engines and in the present case, piston pin manufacturing line is selected for study. With the help of VSM technique current state map of piston pin manufacturing line is prepared and various gap areas have been identified. To address these gap areas and to bridge the gap between current state and proposed state of manufacturing, a few modifications are made in the current state. With consideration of proposed modification, a future state map is prepared and improvements achieved are noticed.

4.1 Preparation and analysis of current state map

Current state map is prepared keeping in view of the lean manufacturing principles. All the data required for this map is taken from the shop floor of the selected industry followed by discussion with workers, supervisors and managers of the industry. A few assumptions are also made for preparation of current state map. From past sales data at the industry under study, it is assumed that maximum demand of piston may reach up to 8100 per month.

The current state map captures information at a particular instance, which may vary from shift to shift. For the sake of analysis, the shift and operator-wise variation (which may be there) is not considered. Effective numbers of working days are 27 per month, number of shifts per day is two and working hours per shift are seven. Available working time per day is 50,400 s. Takt time can be calculated Takt time= {(Available working time per day (seconds)/customer demand per day (units)}={(50400/(8100/27)}=168 s. Current state map is shown in Fig. 3. The demand comes from the customers to planning department of the industry, then planning department send its requirement to different suppliers by manually or by electronics media. Industry keeps raw material inventory of 15 days in their store, material moves from raw material store to finished items store through a number of processes/machines taper turning, drilling, heat treatment, bore grinding, piston pin assembly and hydraulic testing. Details regarding inventory, cycle time, lead time, up time and number of shifts are shown in Fig. 1 against every machine. Actual processing time or the real value-adding time for the existing process is 611 s, whereas production lead time is 290.25 hrs. High work in-process inventory of 610 piston pins and total inventory of 5,610 piston pins are there at factory end. Total manpower required in existing state of piston pin manufacturing line is 11 persons/operators.

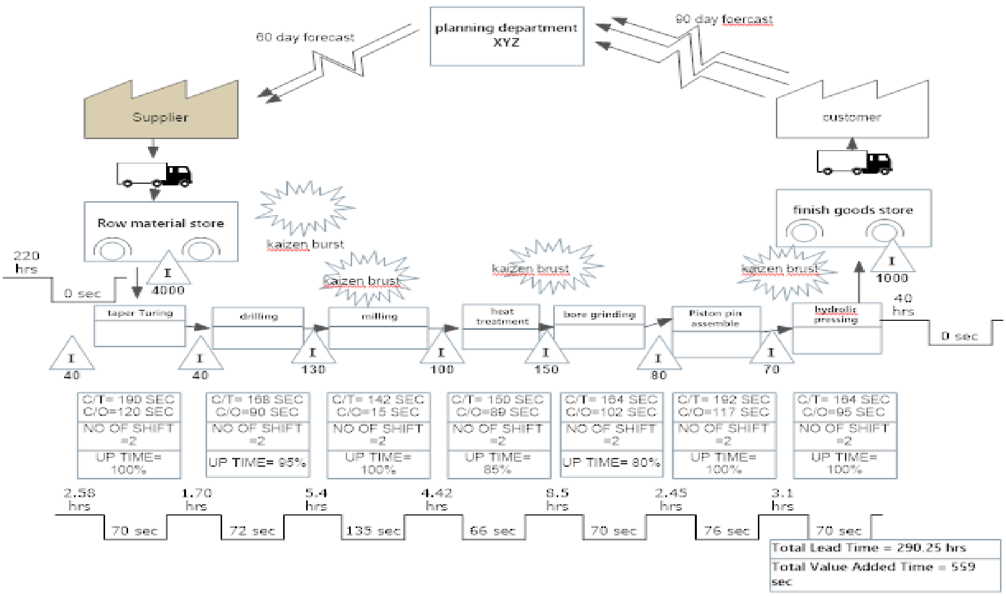

Fig.1 Current state map

4.2 Future state map

Working on the gap areas identified by the VSM of the current state of piston pin manufacturing line, some modification are proposed as indicated in Fig. 2. Store persons are asked to fulfil hourly demand instead of supplying shift-wise. It requires a high degree of information flow and coordination to fulfil hourly demand. To track hourly demand, a Kanban system is proposed. It is suggested that withdrawal Kanban should flow from planning department to dispatch. Similarly, the production Kanban is suggested flowing from dispatch to raw material store, as shown in Fig. 2. The Kanban system brought the necessary schedule and delivery discipline. It is also observed that inventory was high in the production line. Industry was holding 15 days' inventory in the store because of poor communication and a play-safe tendency. Electronic information flow is proposed for the suppliers. It helped in reducing order quantity and inventory at raw material stores. This also helped in making whole supply chain lean and flexible. It is observed that change over time is very high at turning operation and piston pin assembly operation, to synchronize station cycle time with Takt time single-minute exchange of die is proposed at these stations.

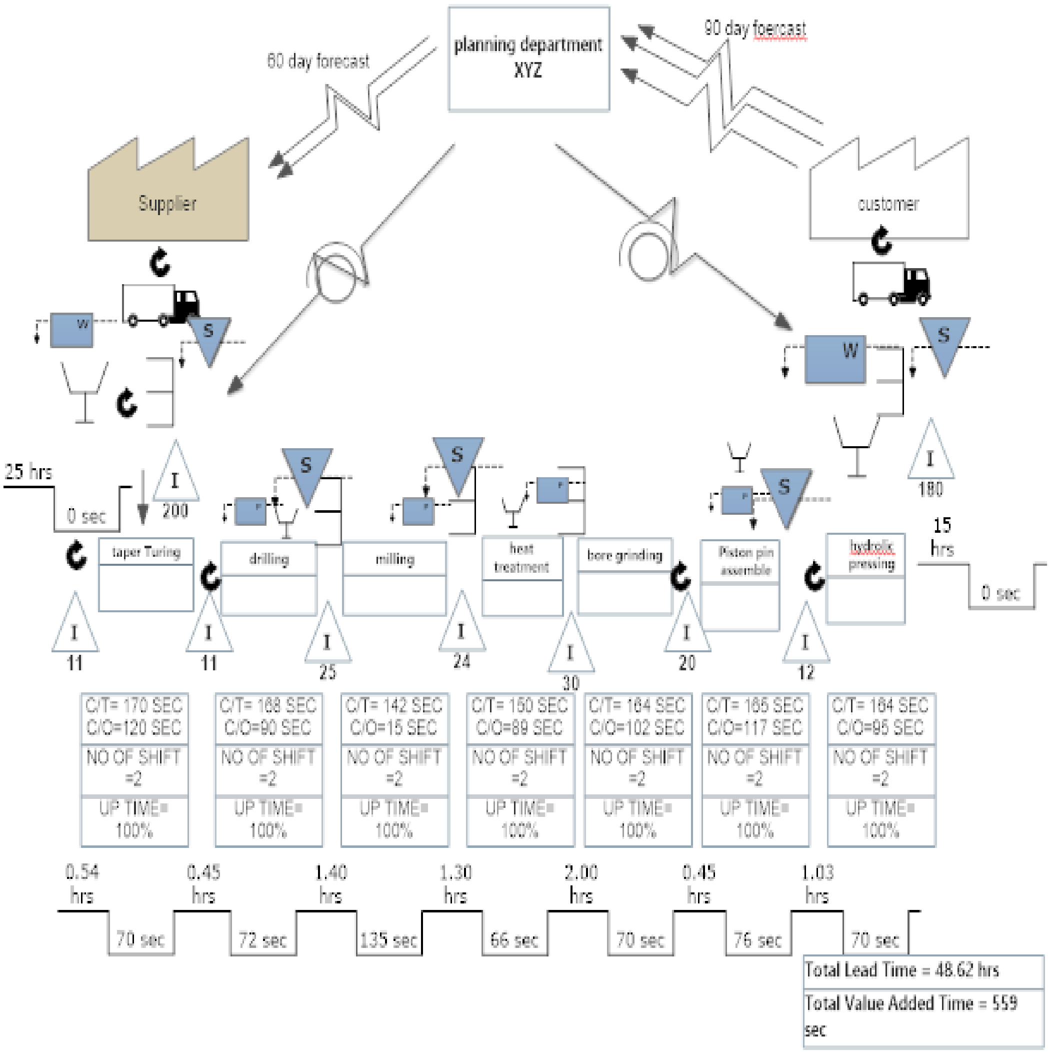

Fig.2 Future state map

IV. Results And Discussions Of Case Study

After the analysis of current state and future state map shown in Figs. 1 and 2, some important findings of the case study are listed below:

1. It is found that total inventory is reduced from 5,601 to 513 and WIP is reduced from 610 to 133, reduction in WIP at individual stations in production line is shown in Fig. 3.

2.Cycle time is reduced from 1,170 to 1,123 s and synchronized with Takt time as shown in Fig. 4.

3.Manpower is decreased from 11 to 9 persons.

4. Total lead time is reduced from 290.25 to 48.62 hrs and production lead time is reduced from 30.25 to 8.62 h, reduction in lead time at individual stations in production line is shown in Fig. 4.

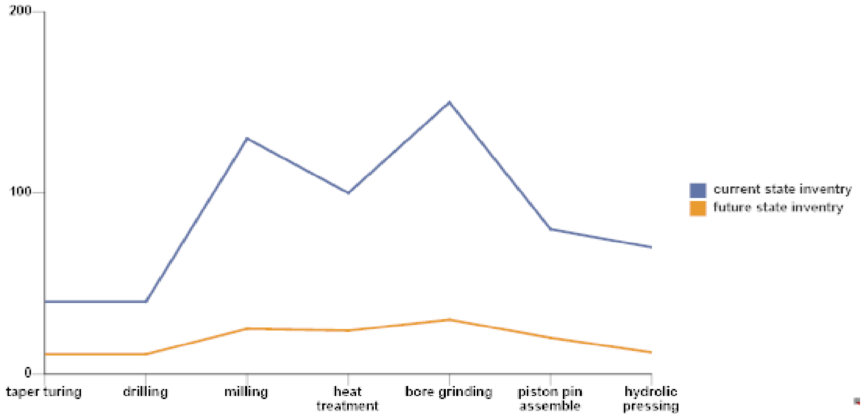

Fig.3 Comparison of WIP in current and future state map

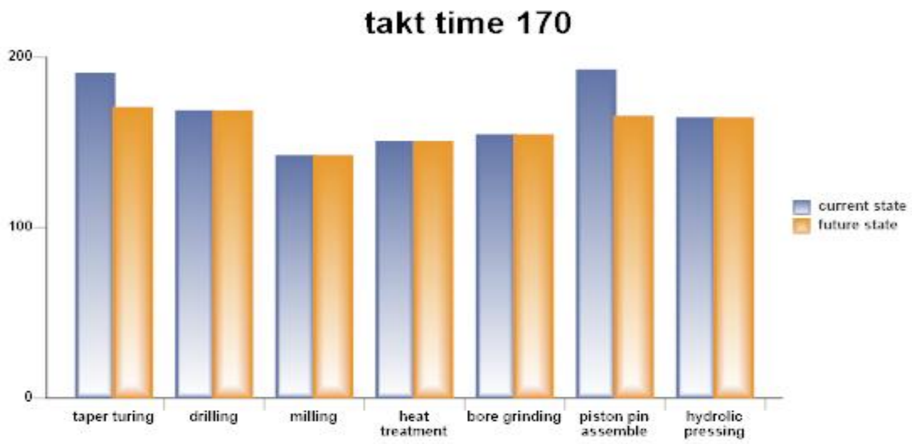

Fig.4 Cycle Time Comparison With Takt Time In Current And Future State Map

V. Conclusion

Lean manufacturing system implemented in this paper is done in an assembly line to eliminate the 8 nonvalue adding wastes like over production, waiting, unnecessary transport movement, defects and unused employee creativity from the manufacturing system and also to create product mix flexibility in the manufacturing cell. Results of the case study conducted in XYZ Indian Industry shows that VSM is a very effective technique for identification and reduction of various types of wastes. The reduction in work in process inventory by 78.20%, finished goods inventory by 82%, product lead time by 82.24%, station cycle time by 4.01%, and manpower required by 18.18%.

Based upon the literature reviewed in this paper on VSM, few areas need further scrutiny:

1. There is a need to discuss cost–benefit analysis of proposed changes made in future state map while applying value stream mapping technique for any specific application.
2. Little work has been done with the help of this technique in the area of vendor management.
3. Effect of changes done in current state during VSM implementation has not seen yet on human factor
4. Comparison of this technique with other waste reduction techniques can also be made.

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