Applying Value Stream Mapping Technique for Production Improvement in a Manufacturing Company: A Case Study

K. L. Jeyaraj · C. Muralidharan · R. Mahalingam · S. G. Deshmukh

Abstract The purpose of this paper is to explain how value stream mapping (VSM) is helpful in lean implementation and to develop the road map to tackle improvement areas to bridge the gap between the existing state and the proposed state of a manufacturing firm. Through this case study, the existing stage of manufacturing is mapped with the help of VSM process symbols and the biggest improvement areas like excessive TAKT time, production, and lead time are identified. Some modifications in current state map are suggested and with these modifications future state map is prepared. Further TAKT time is calculated to set the pace of production processes. This paper compares the current state and future state of a manufacturing firm and witnessed 20 % reduction in TAKT time, 22.5 % reduction in processing time, 4.8 % reduction in lead time, 20 % improvement in production, 9 % improvement in machine utilization, 7 % improvement in man power utilization, objective improvement in workers skill level, and no change in the product and semi finished product inventory level. The findings are limited due to the focused nature of the case study. This case study shows that VSM is a powerful tool for lean implementation and allows the industry to understand and continuously improve towards lean manufacturing.

Keywords Lean production · Work in progress · Value stream mapping · Lead time

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Introduction to Value Stream Mapping

The goal of lean manufacturing is to become highly responsive to customer demand while producing quality products in the most efficient and economical manner by reducing various waste in human effort, inventory, time to market and manufacturing space. This approach focuses around the elimination of all kind of waste. Waste takes many forms and can be found at any time and in any place. It may be found hidden in policies, procedures, process and product designs, and in operations. Waste consumes resources but does not add any value to the product [1]. Waste has defined as anything other than the minimum amount of equipment, effort, materials, parts, space and time that are essential to add value to the product. It has been established beyond doubt that the organizations that have mastered lean manufacturing methods have substantial cost and quality advantages over those which are still practicing traditional mass production [2]. The original concepts and definitions given by [3, 4], about value stream mapping (VSM) demonstrated that it is necessary to map both inter-company and intra-company value-adding streams. Value stream refers to those specifics of the firm that add value to the product or service under consideration. 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''. The process itself is very simple and straightforward. It usually starts with customer delivery and work its way back through the entire process documenting the process graphically and collecting data along the way. Finally it results in a single page map called ''Value stream'', these maps contains data such as cycle time, work-in-process (WIP) levels, quality levels, and equipment performance

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data. Depending on the complexity of the process and the number of components involved additional data required may be collected from other sources. A very important part of the VSM 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, VSM also documents the flow of information within the system. Where the materials are stored (raw materials and WIP) and what triggers the movement of material from one process to the next are key pieces of information. VSM is about eliminating waste wherever it is. VSM can also be applied to the process industry as well as to the service sector.

In this paper, a VSM technique is applied to the flow line manufacturing process in the context of production improvement. The main objectives of this paper are to:

- Reduce the non value added activity.
- Minimize the TAKT time.
- Maximize machine, men and space utilization.

This paper is organized as follows: The literature review is presented followed by the methodology used for the study with a case of a manufacturing company. A step by step approach to implement the future state map is given with the help elimination of wastes principle.

Review of Literature

The following are the brief review of literatures on lean manufacturing concepts. Russell and Taylor [1] suggested that VSM is an excellent tool for any enterprise that wants to become lean. Lean manufacturing also uses tools like one-piece flow, visual control, kaizen, cellular manufacturing, inventory management, Poka yoke, standardized work, workplace organization and scrap reduction to reduce manufacturing waste. Hines and Rich [5] introduced the classification scheme about seven new mapping tools of VSM based on the seven wastes. Hines [6], Lamming [7], Taylor and Brunt [8], Schonberger [9] have made a successful attempt to use VSM as a technique to achieve productivity improvement at the supplier end for an automotive industry. They reported a drastic improvement in production output per person, reduction of work in process and finished goods inventory. Emiliani and Stec [10] described the use of value stream maps for determining the beliefs, behaviors and competencies possessed by business leaders. Abdulmalek and Rajgopal [11] have been applied lean approach in continuous/process sector for application at a large integrated steel mill. VSM was the main tool used to identify the opportunities for various lean techniques.

This paper resulted potential benefits in reduced production lead-time and lower WIP inventory. Bhim and Sharma [12] have implemented lean concepts in a manufacturing firm with the help of VSM. Current state and future state of manufacturing of a firm are compared and witnessed: 92.58 % reduction in lead time, 2.17 % reduction in processing time, 97.1 % reduction in WIP and 26.08 % reduction in manpower requirement. Vinodh et al. [13] have applied VSM for enabling leanness in an Indian camshaft manufacturing organization. The industrial impact as a result of implementing the proposals has been determined. The improvements in leanness parameters such as lead time, processing time and WIP have been found. Bhamu et al. [14] made a case study of VSM implementation in an Indian automotive industry and the article demonstrates the effect of VSM implementation on cost of poor quality, in-process rejections, percentage value addition, lead time, work in process inventory, distance travelled by components and percentage scrap. The results of the study show that the productivity and quality of a company can be improved by implementation of VSM. Saranya and Nithyananth [15] have tried to identify areas of wastes and how these can be reduced or eliminated using lean techniques from the crankshaft assembly supply chain of a leading two wheeler manufactures in south India. They conclude the work with the comparison of work in process, lead time, inventory carrying costs and reduction of value in terms of rupees from the current process to the proposed process. Gill [16] made an attempt to review of existing literature pertaining to application of the VSM tool in hospital emergency rooms/departments. This paper has presented the potential benefits emanating from application of VSM along with assessing its effectiveness in scenarios where it has been implemented already. Furthermore, challenges faced in implementation of the VSM tools are collated. Various solutions to address these challenges have been presented in the light of tribulations faced by today's healthcare industry. Senthil Kumar and Sampath [17] focused on customized implementation of lean tool for minimizing the WIP, line setting time in a knitted T-shirt production industry which in turn reduces the cost of production. The proposed VSM through the support of cellular layout reduces the WIP level significantly, which deliver many advantages in garment production system. The reduction in WIP in the production process will increase the profit by 20–25 % from the existing level. Several researchers have used VSM for different areas in manufacturing such as production improvement, lean system design, inventory control and in service sectors. In this paper VSM technique is applied to flow line manufacturing process of rear pedestal to improve the production.
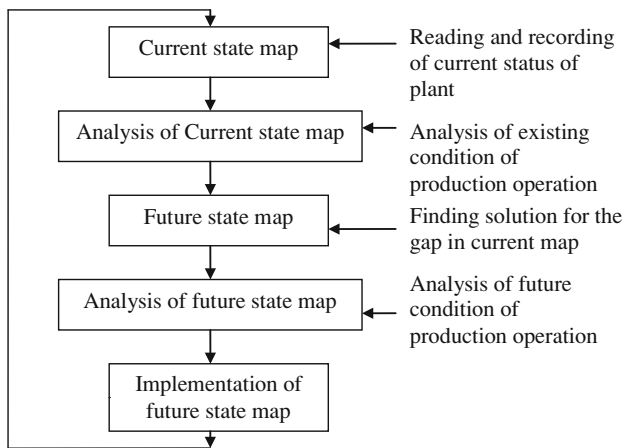
Fig. 1 Research methodology

Fig. 2 Photograph of rear pedestal

Methodology

Mapping of rear front pedestal manufacturing process is done with a pencil and paper using various process symbols of VSM to visualize the flow of material and information as a product takes its way in manufacturing line. Mapping is done keeping in view of the lean manufacturing principles which are the backbone of VSM [9]. These principles are:

- Define value from your customer's perspective.
- Identify the value stream.
- Eliminate the seven deadly wastes.
- Make the work flow.
- Pursue to perfection level.

The proposed methodology is given as a flow chat (Fig. 1), which starts from current state map and its analysis. Finally it is concluded with the future state, analysis and implementation.

The major steps involved in mapping are as follows: [12].

1. Various process symbols of VSM are drawn representing customer, supplier and production control, with sufficient space in between them.
2. All pertinent data related to existing stage of manufacturing such as lead time, process time, change over time and no. of shifts are shown by data boxes below the VSM symbols.
3. The monthly/daily requirements of product along with the number of containers required are obtained.
4. Movement of product is shown with arrows including shipment and receiving data.
5. In between two workstations WIP is shown with proper inventory icons.
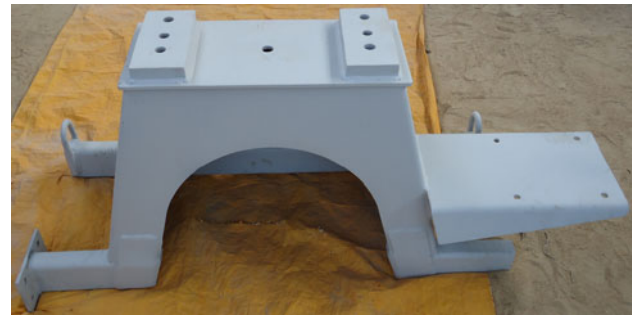6. Major gap areas are identified from the current state map.

7. With the application of lean tools (work study and man machine chart) various gap areas are bridged in order to prepare proposed map.
8. Future state map is prepared and improvements achieved are highlighted.

Current State Map

The firm under study is located near Chennai, Tamil Nadu (India) and deals with manufacturing of rear pedestal, junction plate, upper support right, upper support left to meet the maintenance need of big automobile giants situated near Chennai. The company employs 150 personnel including workers, supervisors, engineers and top management. It operates with 2,000 square feet of space. The case study is dealt with rear pedestal (Fig. 2) manufacturing process and it is used in automobiles. The manufacturing of rear pedestal is flow line manufacturing process. It consists of fitting, welding, grinding, sand blasting and painting (Fig. 3). All the data for current state map were collected with the consultation to workers, supervisors, engineers and managers [18]. Figure 4 shows the current state map of the rear pedestal manufacturing line. The calculation of existing TAKT time is given below with the collected data from the firm's manager. The demand per month of rear pedestal is 300 numbers (10 parts per day), current production capacity per month is 240 numbers (8 parts per day) effective number of working days of the firm per month is 30, number of shifts per day is 2 and working hours per shift is 8.

$$\text{TAKT time}_{\text{Existing}} = \frac{\text{Available working time per day}}{\text{Production capacity per day}}$$
$$= \frac{16}{(240/30)} = 2.0 \, \text{hr}$$

Fitting is the assembly process of the rear pedestal has been done by two workers. There is 14 number of parts assembled every day. The fitting production capacity is 14 parts per day. The welding is next process which is done by 3 workers. The current production is 8 parts per day. Three welding machines

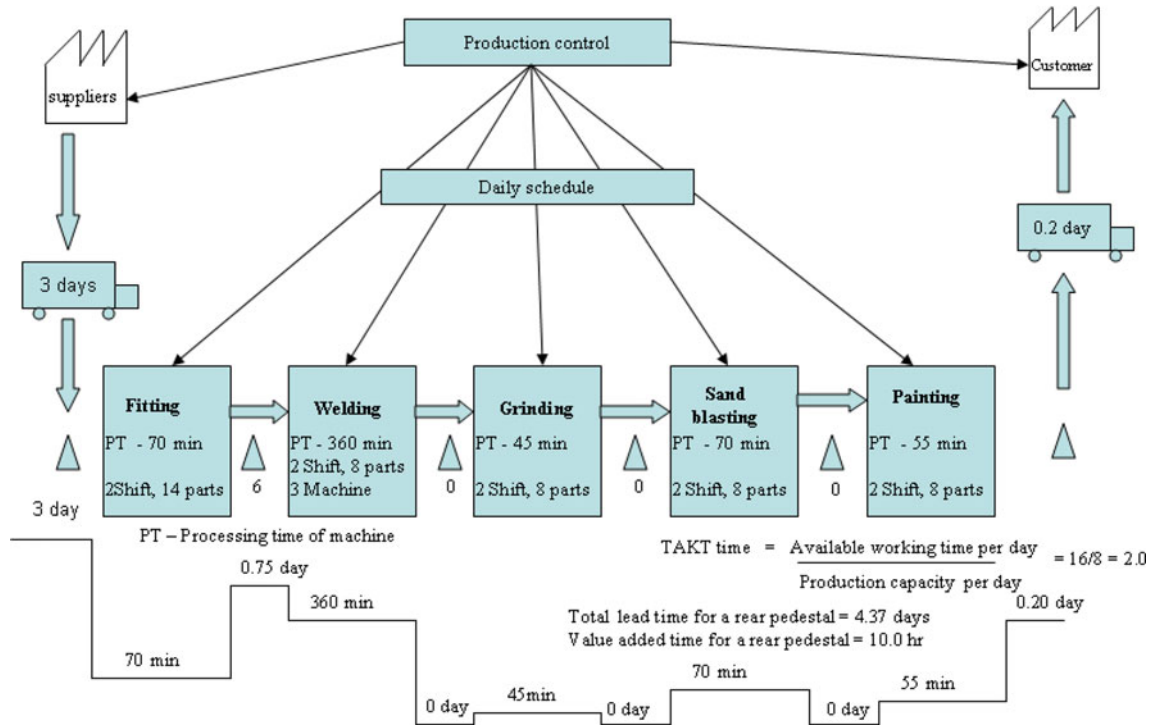**Fig. 3** Rear pedestal manufacturing process

Fig. 4 Current state map

are in operation for completing the 8 parts per day. Grinding is done by single operator and the current production of grinding is 8 parts per day. But grinding production capacity is 21 parts per day. Sand blasting is done by single operator and the current production is 8 parts per day. But blasting production capacity is 14 parts per day. Similarly painting is also done by single operator and current production is 8 parts per day as against the painting production capacity of 17 parts per day. Fitting and welding process are operating at their full capacity. Grinding, sand blasting and painting processes are operating less than its capacity. The current production output of rear pedestals is 8 per day, so welding is operating its full capacity and it is seems to be bottleneck operation. So the production improvement is mainly depends on the improving the utilization and production capacity of the welding process. From Fig. 4, total lead time of a rear pedestal is calculated to 4.37 day [3.95 + 0.42 = 4.37 day]. It is the sum of all the inventory time [3 + 0.75 + 0.2 = 3.95 day] and processing time (PT) [70 + 360 + 45 + 70 + 55 = 600 h (10 h/0.42 day)]. The value added time for a rear pedestal is the sum of all the actual PT or PT, which is equal to 10 h.

Analysis of Current Map

TAKT time required for meeting the customer demand is 1.6 (10 parts/day). The calculation of required TAKT time is given below. But currently the company's TAKT time is 2.0 (8 parts/day) only. So there is short of two components every day. For meeting the TAKT time of 1.6 h the following steps have been initiated.

$$\text{TAKT time}_{\text{Required}} = \frac{\text{Available working time per day}}{\text{Production capacity per day}}$$
$$= \frac{16}{(300/30)} = 1.6 \text{ hr}$$

The bottleneck element in the process of manufacturing rear pedestal is welding. Welding is giving only 8 parts per day. But there was scope to improve the production by minimum 2 parts per day to meet the customer demand. So as to TAKT time can be reached to 1.6. The other process elements fitting, grinding, sand blasting and painting are capable to produce more than 10 parts. That means they were not constraining to achieving the TAKT time of 1.6.

Fig. 5 Man machine chat for current state map

Shift hour	Worker1	Worker2	Worker3	Welding Machine1	Welding Machine2	Welding Machine3
0.5	Working	Working	Working	Worker1	Worker2	Worker3
1.0						
1.5	Working	Working	Working	Worker1	Worker2	Worker3
2.0						
2.5	Working	Working	Working	Worker1	Worker2	Worker3
3.0				1	2	3
3.5	Working	Working	Working	Worker1	Worker2	Worker3
4.0						
4.5	Working	Working	Working	Worker1	Worker2	Worker3
5.0						
5.5	Working	Working	Working	Worker1	Worker2	Worker3
6.0						
6.5	Working	Working	Working	Worker1	Worker2	Worker3
7.0						
7.5	Working	Working	Working	Worker1	Worker2	Worker3
8.0						
8.5	Working	Working	Working	Worker1	Worker2	Worker3
9.0				4	5	6
9.5	Working	Working	Working	Worker1	Worker2	Worker3
10.0						
10.5	Working	Working	Working	Worker1	Worker2	Worker3
11.0						
11.5	Working	Working	Working	Worker1	Worker2	Worker3
12.0						
12.5	Working		Working	Worker1		Worker3
13.0		Working		Worker2		
13.5	Working		Working	Worker1		Worker3
14.0		Working				Worker2
14.5	Working		Working	Worker1		Worker3
15.0		Working		Worker1	7	8
15.5	Working		Working	Worker1		Worker3
16		Working				Worker2

Only welding is the key to achieve the TAKT time 1.6. Three workers were working in the welding department and they were taking rest after every half an hour. Their productivity was identified by plotted their working in the man machine chart (Fig. 5).

Future State Map

The new strategy of working, for welding and grinding process is proposed here to improve the production of rear pedestal. Three workers of the bottleneck welding process and grinding operator were combined together for working in both the welding and grinding operations; since the grinding worker is having idler time. This was justified with actual grinding production per day and its capacity available. The work study was conducted on this combined working procedure and man machine chart was plotted (Fig. 6). It shows that the combined operation can able to produce 10 rear pedestals per day without any over load to the workers. Very often a clear picture of the relationship of the operator's working time and the machine time can be obtained by showing the information graphically to scale. Such a record is called as man machine chart. In the man machine chat (Figs. 5, 6), man and machine are taken as top horizontal axis and time taken is taken left vertical axis. A man machine chart graphically represents the relationship between the manual work performed by one or more operators and one or more machines involved in a manufacturing process. Given the different work steps required in a production process to load, operate and unload machines in conjunction with the process times of the machines themselves the man–machine chart is used to determine the highest production level that can be achieved given the resources available. It is desirable to eliminate idle time for the worker, but it is equally important that the machine be kept operating as near capacity as possible. Table 1 provides a comparison of man and machine utilization before combining and after combining the grinding and welding operations (after training). The values for this tabulation are taken from the Figs. 5 and 6.

Analysis of Future State Map

Figure 7 shows the future state mapping of the rear pedestal process. This is an optimized process based on the man machine chart (Fig. 6). The fitting process produces 14 parts

TIME (hr/min)		WORKER1	WORKER2	WORKER3	WORKER4	WELDING MACHINE1	WELDING MACHINE2	WELDING MACHINE3	GRINDING MACHINE
1	15	WR1		WR3		WR1		WR3	WR2
	30	WR1		WR3		WR1		WR3	WR4
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		
2	15	WR1		WR3		WR1 (1)		WR3	WR2
	30	WR1		WR3		WR1		WR3	WR4
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
3	15	WR1		WR3		WR1	(2)	WR3	WR2
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2 (3)		
	60		WR2		WR4	WR4	WR2		WR3
4	15	WR1		WR3		WR1		WR3	WR4
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
5	15	WR1		WR3		WR1 (4)		WR3	WR2
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR3
6	15	WR1		WR3		WR1		WR3	WR4
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
7	15	WR1		WR3		WR1		WR3	WR2
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR3
8	15	WR1		WR3		WR1 (5)		WR3	WR4
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
9	15	WR1		WR3		WR1	(6)	WR3	WR2
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2	(7)	
	60		WR2		WR4	WR4	WR2		WR3
10	15	WR1		WR3		WR1		WR3	WR4
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
11	15	WR1		WR3		WR1 (8)		WR3	WR2
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR3
12	15	WR1		WR3		WR1		WR3	WR4
	30	WR1		WR3		WR1		WR3	
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
13	15	WR1		WR3		WR1	WR3		WR2
	30	WR1		WR3		WR1	WR3		
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR3
14	15	WR1		WR3		WR1 (9)	WR3 (10)		WR4
	30	WR1		WR3		WR1	WR3		
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR1
15	15	WR1		WR3		WR1	WR3		WR2
	30	WR1		WR3		WR1	WR3		
	45		WR2		WR4	WR4	WR2		
	60		WR2		WR4	WR4	WR2		WR3
16	15	WR1		WR3		WR1	WR3		WR4
	30	WR1		WR3		WR1	WR3		
	45		WR2		WR4	WR4	WR2		WR3
	60		WR2		WR4	WR4	WR2		WR1

Fig. 6 Man machine chat for state future map

Table 1 Comparison of man machine chart for uncombined working and combined working in welding and grinding machines operations

| | Un combined working [3 welding operators working in 3 welding machines and 1 grinding operator working in 1 grinding machine] (Fig. 5) | | | | Combined working [3 welding operators and 1 grinding operator working combined in both 3 welding machines and 1 grinding machine] (Fig. 6) | | | |
| | Man | | Machine | | Man | | Machine | |
	Welding O/P (3 nos)	Grinding O/P (1 no)	Welding M/C (3 nos)	Grinding M/C (1 no)	Welding O/P (3 nos)	Grinding O/P (1 no)	Welding M/C (3 nos)	Grinding M/C (1 no)
Idle Time (h)	24	10	24	10	18	8.5	16	8.5
Working Time (h)	24	6	24	6	30	7.5	32	7.5
Total cycle time (h)	48	16	48	16	48	16	48	16
Utilization (%)	50 %	38 %	50 %	38 %	63 %	47 %	67 %	47 %
Utilization [welding + grinding] (%)	47 %		47 %		59 %		62 %	

O/P operator, *M/C* machine
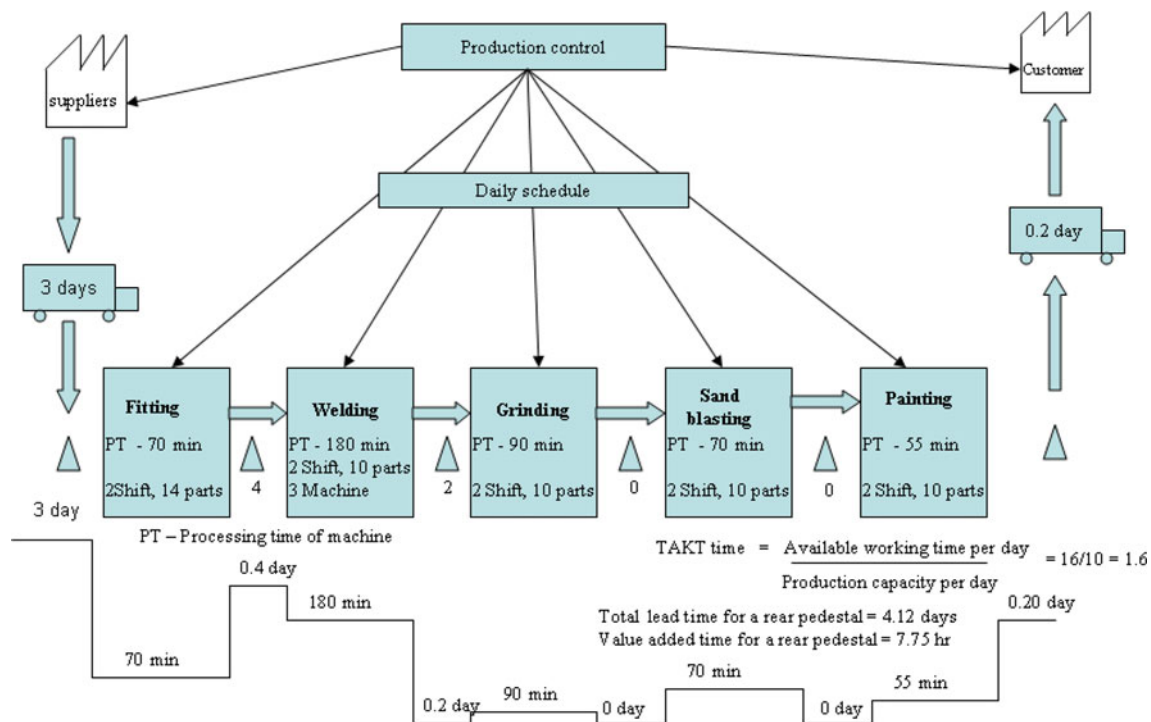
Fig. 7 Future state map

per day and hence is having 4 parts as inventory. The welding process produces 10 parts per day. It is recommended to keep two inventories before grinding process for smooth running of the line. The other processes sand blasting and painting are restricted to produces only 10 parts to make the line balanced. From the Fig. 7, total lead time of a rear pedestal is calculated to 4.12 day [3.8 + 0.32 = 4.12 day]. It is the sum of all the inventory time [3 + 0.4 + 0.2 + 0.2 = 3.8 day] and PT [70 + 180 + 90 + 70 + 55 = 465 h (7.75 h/0.32 day)]. The value added time for a rear pedestal is the sum of all the actual PT or PT, which is equal to 7.75 h.

Utilization of manpower and machine for current state map is given in Table 2. Table 3 shows future state map utilization of manpower and machine. Table 4 compares future state map to the current state map such as TAKT time, production time, skill improvement, inventories and utilization. The future state mapping decreases the TAKT to 1.6 from 2.0. In future state mapping total lead time and value added time decreases from the current state map and this can be seen from visually in Figs. 4 and 7. Combined welding and grinding operation makes the workers multi-skilled. The new strategy of combining welding and grinding process increases the man and

Table 2 Man machine utilization of entire flow line before combining welding and grinding operations

Future state map	Manpower utilization					Machine utilization				
	Fitting O/P (1 no)	Welding O/P (3 nos)	Grinding O/P (1 no)	Sandblasting O/P (1 no)	Painting O/P (3 nos)	Fitting M/C (1 no)	Welding M/C (3 nos)	Grinding M/C (1 no)	Sandblasting M/C (1 no)	Painting M/C (3 nos)
Idle time (h)	0	24	10	4.4	6.8	0	24	10	4.4	6.8
Working time (h)	16	24	6	11.6	9.2	16	24	6	11.6	9.2
Total cycle time (h)	16	48	16	16	16	16	48	16	16	16
Utilization (%)	100 %	50 %	38 %	73 %	58 %	100 %	50 %	38 %	73 %	58 %
Utilization [line] (%)	60 %					60 %				

O/P operator, *M/C* machine

Table 3 Man machine utilization of entire flow line after combining welding and grinding operations

Future state map	Manpower utilization					Machine utilization				
	Fitting O/P (1 no)	Welding O/P (3 nos)	Grinding O/P (1 no)	Sandblasting O/P (1 no)	Painting O/P (3 nos)	Fitting M/C (1 no)	Welding M/C (3 nos)	Grinding M/C (1 no)	Sandblasting M/C (1 no)	Painting M/C (3 nos)
Idle time (h)	0	16	8.5	4.4	6.8	0	18	8.5	4.4	6.8
Working time (h)	16	30	7.5	11.6	9.2	16	32	7.5	11.6	9.2
Total cycle time (h)	16	48	16	16	16	16	48	16	16	16
Utilization (%)	100 %	63 %	47 %	73 %	58 %	100 %	67 %	47 %	73 %	58 %
Utilization [line] (%)	67 %					69 %				

O/P operator, *M/C* machine

Table 4 Analysis of current and future state map

S. no.	Improvement factors	Current state map	Future state map	Percentage of improvement
1	TAKT time	2.0	1.6	20
2	Value added time for a rear pedestal (h)	10.00	7.75	22.5
3	Total lead time for a rear pedestal (days)	3.95	3.76	4.8
4	Skill improvement	No multi-skill	Multi-skill	Initially no multi-skill operators, now 4 operators are multi-skilled
5	Number of product per day	8	10	25
6	Man utilization $_{Entire\ flow\ line}$ (%)	60.0	67.0	11.7
7	Machine utilization $_{Entire\ flow\ line}$ (%)	60.0	69.0	15
8	Space utilization $_{Entire\ flow\ line}$ (%)	8 parts per 2,000 square feet	10 parts per 2,000 square feet	25
9	Man utilization $_{Bottleneck}$ (%)	50.0	63.0	26
10	Machine utilization $_{Bottleneck}$ (%)	60.0	67.0	7
11	Space utilization $_{Bottleneck}$ (%)	8 parts per 400 square feet	10 parts per 400 square feet	25
12	Inventory of products	6	6	No improvement

machine utilization. Utilization of man and machine is depends on the bottleneck process in a flow line manufacturing. Here welding process is bottleneck and it determines the utilization of man and machine for the entire flow line. If the welding utilization increases the line utilization will increase. The calculation of line utilization of manpower and machine is explained in Tables 2 and 3. Inventory of the process is unchanged for the both current and future state mapping. The current state mapping was having 6 number of fitting process inventory. But in the future state mapping 4 numbers fitting process inventories and two number welding process inventories were kept. Considering space utilization, the warehousing space is not considered in this work. Since all the manufactured rear pedestals in a day are being shipped same day. The layout of the plant and the inventory levels are not changed in the present and future state mapping. So the plant space utilization can be quantified with the production per unit area [19]. The total plant area is 2,000 square feet and bottleneck welding area is 400 square feet. In the future state map production per unit area has increased from 8 parts per 2,000 square feet to 10 parts per 2,000 square feet. Considering the bottleneck welding process, production per unit area has increased from 8 parts per 400 square feet to 10 parts per 400 square feet.

Conclusions

It is proven beyond doubt that VSM is a powerful tool for lean manufacturing and allows firms to understand and continuously improve its understanding towards lean. It links people, tools, processes and even reporting requirements to achieve lean goals. It provides clear and concise communication between management and shop floor teams about lean expectations, along with actual material and information flow. Over the years, many lean manufacturing tools to support value stream have been developed and many more are being proposed. Lean Manufacturing aims to identify and eliminate waste (7 muda) to improve the performance of the business. The seven waste classifications are, over production, inventory, waiting, motion, transportation, defects, over processing. Today, there exists a plethora of different tools and techniques developed for different purposes and waste reduction or elimination. In VSM, for reducing or eliminating these 7 wastes a numerous tools (kanban, standardization of work, work place organization, inventory policy, pull-push production system and others) have been applied. In this paper standardization work (man machine chart) is taken for the reduction of the waste "waiting". The idle time of the man and machine was identified. Strategically combined work force between the machining centres (welding machine and grinding machine) and training reduced the idle time of both men and machine. The new man machine chart was completed

with reduced idle time (increased utilization) of the welding process. This process increases the utilization (man and machine) of entire flow line.

This paper compared the current state and future state of a manufacturing firm and witnessed 20 % reduction in TAKT time, 22.5 % reduction in value added time, 4.8 % reduction in total lead time, 20 % improvement in production, 9 % improvement in machine utilization, 7 % improvement in both man and machine utilization and no change in the inventory level.

Reduction in TAKT time will bring more orders to firm, since reduced TAKT time increases the production capacity of the firm and meets the customer demand in terms of delivery of products. Satisfied customer can only provide repetitive orders. The repetitive orders bring the profitability to the firm. Reduction in value added time finds the new way of working in a scientific manner. It avoids the unnecessary idle time, and provides optimized way of doing the work. Reduction in lead time eliminates lengthier process time of the product. It avoids inventory of all the forms (finished and semi finished). Combined welding and grinding operation makes the workers multi-skilled. Multi-skill work force manages the production loss in a critical situation such as absenteeism, strike and other want of worker related issues. Multi-skill work force will create flexibility in manpower allocation for the managers and supervisors. The new strategy of combining the welding and grinding process increases the man and machine utilization. Increased utilization of both man and machine increases firm return on investment. This also helps the firm break even in faster time. No change in inventory levels of the current and future state mapping, and it is always better to keep inventory before the bottleneck process. Bottleneck elements need to be utilized its fullest capacity. Any under utilized capacity of bottleneck elements will reduce the production output. So it is necessary to keep inventory before the bottleneck process. In case of any delay in the upstream element of bottleneck element, this inventory avoids the starving of bottleneck element. So welding process is having four number inventories. Flow line manufacturing without bottleneck operation will not yield the rated product output. It is better to have one or more bottleneck elements. In the future state mapping, due to combined welding and grinding process is appeared as second bottleneck process. Obviously it also needs to be fully utilized, so two number inventories are provided in front of grinding operation. Future state mapping of the flow line manufacturing; with less TAKT time, with two bottlenecks, with minimum inventory in front of bottleneck process, reduced lead time, reduced value added time and with the multi-skilled work force surly bring the consistent performance and profitability to the firm.

VSM could be applied to both manufacturing and service industries for improvement in production process using the

lean principles. Different levels of mapping could be possible for any industry; process level (cell or department), single plant (door-to-door), multiple plants (between subsidiaries) and across companies. Culture change is a long term philosophy is highlighted as the foundational thing in VSM for industries to sustain success. VSM like any other lean tool is human centered. Constructive feedback and open-mindedness towards incremental success would help the team in identifying the waste and subsequently eliminating it. VSM is a continuous improvement tool based on PDCA cycle (plan, do, check and act). The research methodology (Fig. 1) of this paper follows the PDCA approach and could be applicable for any industries to their continuous improvement program. In Fig. 1, current state map and its analysis is plan, preparing future state map is do, analyzing future state map is check and implementing future state map is act. VSM practitioners should thus iteratively look for sources of waste in an effort to minimize it. Lastly, the workgroup should communicate their achievements to other colleague in order to inspire them. Extrinsic to the workgroup: Management support to should ensure that the VSM workgroup comprises of employees who are closest to the problem. Furthermore, the management should empower the employees with authority and responsibility to make the necessary changes in a timely manner. Management should support lean principles across the organization instead of cherry picking the tools and/or departments for implementation.

Appendix 1

TAKT Time

TAKT time is defined as rate at which a company must produce a product to satisfy its customer demand. It is calculated by dividing available working time per day (in minutes or seconds) to customer demand per day (in relevant units).

TAKT time = Available working time per day/Customer demand per day.

Production Lead-Time

It is the total time a component takes in its way through the shop floor, beginning with arrival of raw material to shipment of finished/semi finished goods to customer.

Value Adding Time

Value adding time is the time which is utilized in adding actual value to the product.

Current State Map

It describes the existing/current position of shop floor of any manufacturing facility.

Future State Map

It describes the proposed/future position of shop floor of any manufacturing facility in order to bring some improvement.

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