Value stream mapping in a discrete manufacturing: A case study

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Abstract— **The purpose of this paper is to apply value stream mapping (VSM) for making improvement roadmap in a discrete manufacturing organization. This study provides an up-to-date, review of value stream mapping. A systematic methodology is presented in this paper for selecting product family and processes for improvements. A current state map is developed after critical observations, calculations, and analysis for identifying wastes in current system. The various tools of lean manufacturing are then discussed to establish improvement roadmap, which lead to future state mapping. The improvements evaluated on key performance indicators such as lead time, inventory reduction and increased value addition. Few tangible benefits are, reduction in lead time by 59%, improvement in VA/NVA ratio by 138%, and reduction in inventory by 61%. In order to implement VSM in a discrete manufacturing organization, this study gives a complete overview of conducting value stream mapping study. The value stream mapping study reported is an original work of the authors which conducted in discrete manufacturing scenario represented by low volume with high variety products. With this context of complexity to develop value stream maps, the study is considered to be highly valuable.**

Keywords— *Value stream mapping, lean manufacturing, waste reduction, takt time, value*

1. Introduction

Manufacturing companies need to redefine and redesign their production systems in response to the competitiveness demanded by the challenges of present markets [25]. Within such scenario, companies experience the need for improvement in its manufacturing processes, in order to provide high-quality products at affordable prices and on time. To this end, managers' concerns in reducing waste which are growing. The lean implementation allows a company to reinforce the various stages that lead to operational excellence, continuous improvement, and elimination of activities that don't add value [10]. Lean manufacturing is originated in Toyota with names 'Toyota production system (TPS)' beginning back in the 1960s [13], [17]. It holds significant promises for substantial advantage for improvement of communication and integration within the organization and supply chain [23]. Lean enablers are considered as a set of tools, techniques and suggestions for implementation and execution of lean principles and help business units to step toward leanness [23]. Lean manufacturing system is seen by practitioners as an answer for cost reduction production system, which encompasses tools and strategies for improvement [29].

VSM is such one of the tool which depicts the entire system under study on a single sheet of paper, using symbolic illustrations and icons [19]. A value stream consists of all the materials and information required in the manufacturing of a particular product and how they flow through the manufacturing system [7], [19]. VSM is described as a technique used for the diagnosis, implementation, and maintenance of a lean approach [10]. VSM is a powerful tool that enables the visualization and understanding of the flow of material and information through the value chain [15]. The main purpose of this tool is to reduce the time between placement of order by the customer and the time of delivery of the product [2]. Benefits gained from using VSM to promote the lean implementation are well supported in the literature [23].

Some VSM benefits are [10]:

- Allows a broad view of the entire flow;
- Helps to identify wastes;

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- Shows the relationship between material and information flow;
- Provides a simple and standardized way to treat procedures;
- Makes decisions more “visible,” allowing the previous discussion of possible changes and improvements and;
- Forms the basis for an action plan.

Literature suggests wide application of VSM: automobile manufacturing [2], [15], [28], [34], water-heater manufacturing [30], camshaft manufacturing [32], process industry [18] and coffee industry [19]. Although, it is not restricted to manufacturing, VSM found its applications in various support functions as well: sales process [4], truck transportation [21], supply chain of cottonseed industry [26], electrical manufacturing services [27], healthcare [11], housing construction [37], upholstery furniture engineering process [33], project management [6] and new product development process [8] [31].

Despite the benefits as discussed in above, Ref. [10] pointed to the difficulties and limitations while using VSM. The preceding study highlighted the difficulties on the front of capturing process and material flow between the processes, correct observation of wrongdoing and lack of standardization which makes this process stiff. This specially is problem in discrete manufacturing environment, characterized by high number of SKU’s, variable demand per SKU, variable batch size and short runs of production [20].

It is undeniable that the application of VSM provides important benefits to the productive process. That is why it is a practice, applied at so many companies and studied at several universities and research centres. Even with all its benefits, when mistakenly applied, VSM can generate poor results which lead to bad decisions, both technically and financially. Therefore, many interesting opportunities exist for making more rational use of the VSM tool and thus provide more reliable results. The purpose of this paper is to present a case study of VSM to shed light on the methodology adopted on complex product-process manufacturing system, which will help practitioners to understand the VSM and its application in a better and practical way.

The remainder of this article is organized as follows: the next section reviews the relevant literature review related to VSM. A brief summary of company background is provided in section 3. Section 4 details the implementation procedure of VSM to explore underlying problem. The details of current state analysis to develop future state are provided in section 5. Section 6 highlights the expected benefits after implementation of proposed model and finally section 7 summarizes the entire article and provides the direction of future research.

2. Literature Review

Ref. [35] presents lean thinking in a systematic way; and summarized five critical elements of lean implementation, i.e., value, value stream, flow, pull, and the pursuit of perfection [36]. According to Ref. [7], any task in a manufacturing facility can be classified into one of three categories: incidental work, value-added work, and muda. Incidental processes are processes such as inspection that do not add value to the product but are required in the current production system. Value-added processes add value to the product, such as the final assembly of a product. Finally, muda, or non-value added processes, are defined as any process that does not add value to the product and is not required by the current production system. The main function of VSM is to identify opportunities for improvement and the elimination of waste with support from the operational team.

Value Stream Mapping is a pencil and paper tool that helps you to see and understand the flow of material and information as a product makes its way through the stream [14]. The participants or team is required to obtain essential information about the manufacturing processes. It involves mapping of production path from customer to the supplier by visual representation/symbols of every process in material and information flow [10]. Then ask a set of specific and key questions resulting in mapping of ‘future state, off-course along with the action plan to achieve it [15]. Ref. [22] emphasized the use of simulation software for VSM to transform database in simulation models easily and in a short time. This also expedites the implementation of improvements to the system quickly.

VSM mainly focuses on the analysis and improvement of disconnected flow lines in manufacturing environments [24]-[25]. With regard to the VSM application process, it is based on five phases put into practice by a special team created for such a purpose [24]-[25]. The phases are (1) selection of a product family; (2) current state mapping; (3) future state mapping; (4) definition of a work plan; and (5) achievement of the work plan.

Since the inception of VSM, an extensive literature has identified the strengths of lean tools when applied in the real-world and across different fields [36]. VSM has proved effective in identifying physical details of the manufacturing process and has been introduced as a functional method to help practitioners reorganize manufacturing systems [36]. Lower production costs, faster response time to the customer and higher quality of products are therefore outputs that can be expected when applying VSM to a production process [15].

Literature suggests the use of lean metrics like lead time, value added time, cycle time and takt time when applying the VSM tool [1], [15]. Few definitions of the KPI's or lean metrics are given below:

Lead time is the time a product takes to flow through the value stream or the process, from start to finish [15], [24].

Value added time refers to the time of the operations that, according to the customer/client, add value to the product and for which he is willing to pay [15], [24].

Cycle time is defined by the period of time between repetitions of the same task. It is, therefore, the time taken by all operations of the slowest station/operator of the process [15], [24].

Takt time is the frequency in which a product must be produced, to meet the client's demand. This metric is used to synchronize the production and the sales cadence [15], [24].

Takt Time can be determined using the following formula:

$$Takt\ time = \frac{Available\ work\ time\ per\ shift}{Customer\ demand\ rate\ per\ shift}$$

3. Company background

The company under this research study is a part of large organization (ABC) which is stretched into diversified businesses. This company is OEM (Original equipment manufacturer) and produces an electrical products. The products are of wide range classified on the basis of output (X KW to Y MW) to fulfill the diversified demands of customers based on their needs. They are in discrete manufacturing, represented the environment of low volume and high variety of products. The manufacturing technologies used are casting, machining, assembly and painting. Company ABC has a wide variety of customers located all over the world. Company ABC's products are standard catalog products as well as made to their customers' exact specifications (eg. MTO – Make to Order).

Company has sales offices which handles enquiries from customers, once they gone through the exact requirements, next step is to update into standard checklist. Catalogues for different product families are developed to make enquiry process easy. This checklist along with order quantity is then forwarded to engineering team to release BOM (bill of material) and drawings, followed by release of production orders by Materials Management team. Next step is to order the components and lined up in-house production based on its manufacturing lead time. In this sector, all the manufacturers are competing on basis of lead time. However, Company ABC is facing challenge of shortening the manufacturing lead time of 3 weeks from existing 32 days (>4.5 weeks). In order to achieve this, company has already started to explore various tools and techniques that fall under lean manufacturing. Keeping this in mind, company ABC wants to use VSM to explore the wastes in manufacturing and eliminate them.

Although the managers had knowledge about how lean manufacturing could help the company, the workers at Company ABC had yet to complete a lean manufacturing project, and expressed their desire to transform the facility using lean strategy in order to increase the efficiency of their plant. Although lean has potential applications enterprise-wide in Company ABC. Hence, Company ABC agreed and offered lean project which involved study and implementation of VSM for its major product line. For this purpose, a VSM team is formed to collect data, analyse it and implemented the suggestions to improve manufacturing efficiency.

4. VSM to develop current state

VSM provides a depiction of both current-state and future-state maps. The difference between the current state and potential future state is helpful in visualizing what conditions would work when improvements are conducted. Current state map serve as the basis for developing future state map that eliminate waste (non-value added) steps and interfaces while pulling resources through the system and smoothing flow.

VSM provides a visual platform to capture the input/output of “door to door” steps, involved resource, cycle time and utilized time [31]. This distinct feature has replaced VSM over conventional recording approaches from analysis perspective. The five principles of lean management forming the backbone of VSM are: defining value for the product from customer’s point of view, developing value stream and eliminates wastes, uninterrupted flow, pull system by avoiding push to customers and pursue to reach the perfection level [35], [36]. Based on these lean principles, any activity being performed can be classified into following three categories: 1) Value added activity: create values perceived by external customers for which they willing to pay; 2) Non value added activity but necessary: activities which may not create value for external customers, but they are necessary due to un-avoidable circumstances; 3) Waste: activities that add no value for external customers, these activities should be identified and eliminated.

Further to this, Ref. [31] stressed the importance of increasing the ratio of value-added time, and the same time decreasing the ratio of non-value added but necessary and waste time. In order to meet these expectations, there is need to find out wastes associated with material and information flow in the manufacturing. The seven wastes includes [31], [35], overproduction, inventory, extra processing, transportation, waiting/queuing, excess motion and defect work.

The overall methodology adopted in this research is shown in Figure 1, which shows the steps involved in implementation of VSM and their objectives in a single line. The initial analysis was conducted to select the product family for potential improvements. The Pareto analysis was conducted to prioritize the products based on the order quantity and total revenue resulting of it. In the next step, the current state is mapped with the prospect of reaching to the improved future state. The action plan is prepared with an objective of reaching to future state and realize all the benefits by eliminating wastes. Next sub-section discusses the actual data collection for the underlying study.

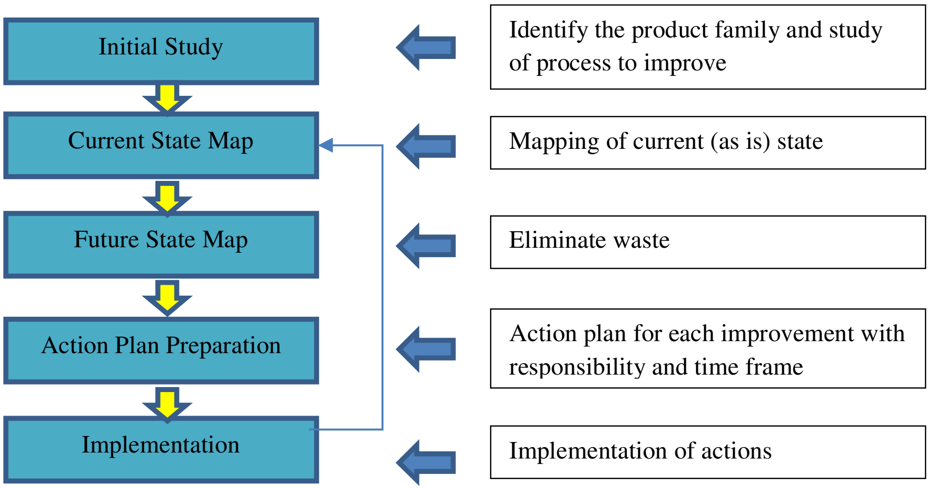

Figure 1. VSM implementation phases with objectives

4.1. *Selection of product family*

The starting point of conducting the VSM study in discrete manufacturing and low volume with high variety products is a selection of product family. The approach for the selection of product family is through performing Product-Quantity Analysis (P-Q analysis) which is the classical approach for product mix segmentation. The P-Q chart shown in figure 2, is in the form of Pareto chart which shows quantity along with cumulative percentage in order of decreasing quantity. Further to this P-Q analysis, the revenue is taken into consideration as an additional parameter for better representation. Product-Revenue Analysis (P-R analysis) is performed in the form of Pareto chart which shows revenue along with cumulative percentage in decreasing trend (see figure 3). The combination of two Pareto analyses (P-Q and P-R analysis) leads to the Classification Matrix (Table. 1) that defines nine distinct products classes ranging from High-High (upper class) and Low-Low (lower class).

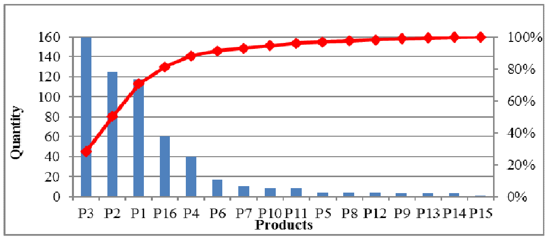

Figure 2. Product-Quantity Chart

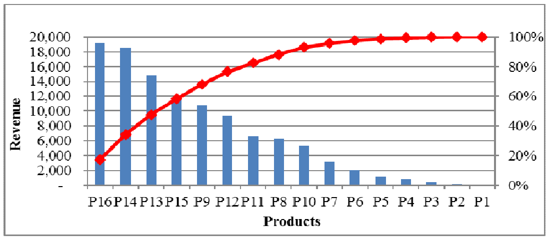

Figure 3. Product-Revenue Chart

Table. 1 Priority Matrix

High

Revenue

P14, P13, P12, P15, P9	P16	
P8	P6, P7, P10, P11	
P5	P4	P1, P2, P3

Low **Quantity** High

Ref. [3] have underlain the logic that high volume products are responsible for the largest part of non-value-added costs such as: material handling, WIP, queuing, and other operational costs. Figure 2 clearly shows that the product P1, P2 and P3 are contributing highest (70%) in accordance with quantity. Hence, we selected these products (P1, P2 and P3) for VSM study.

4.2. *Product-Process Matrix*

The second step of the framework consists in the identification of the processes that, being common in more than a product, act as a possible group of products for study. Additionally, it summarizes machines being shared by more than a product family, which could be a possible constraint for lean manufacturing implementation. Ref. [3] suggests a facility layout must possess the following characteristics, to achieve a continuous and leveled flow:

- flow between consecutive pairs of operations takes place over short travel distances;
- flow is unidirectional with minimum backtracking or cross-flows between machines; and
- flow paths in the cell must consist of smooth contours.

In another word, machines that are dedicated to a single product family offers an opportunity to improve the layout structure. On the contrary, machines that are shared by products belonging to different families act as constraints for layout. Thus, before proceeding with VSM, it is necessary to identify all the processes/machines that are used by more than a family. Table 2 is a product-process matrix, it indicates different product families eg. Family 1 – Product 1, 2 and 3, Family 2 – Product 4, 5, 6, 7, 8, and 9, finally Family 3 – Product 10, 11, 12, 13 and 14. Products 15 and 16 remained independent products and could not become part of any product family.

4.3. *Drawing the current state map*

The production processes of selected product/group were carefully observed and studied through a structured "Gemba walk". Gemba refers "the real place" where the actual actions are executed. Gemba walk encourages by "go-see" principle. In another word, getting out of office and walking the process. This enables discovering issues and fix them. Ref. [31] pointed two advantages of Gemba walk for continuous improvement: first, powerful way to support continuous improvement and process standardization with the help of company leaders, managers and supervisors; and second, it helps building relationships with team leaders by getting to know teammates better and helping them improve the processes.

By doing so a sense and sequence of material and information flow were gained. The mapping is done through the door to door flow of a system (also called as dock-to-dock) starting at the customer end and going upstream towards supplier end. This way mapping was began by process directly linked to the customer which should set the pace for other processes further upstream. Value stream map was hand drawn on a paper. The reason for a paper and pencil approach to mapping instead of using a computer is that by hand drawing key points can be understood and the focus will shift on understanding the flow instead of how to use a computer. The main point of value stream mapping is not the map but understanding the material and information flow.

Table 2 Product-Process Matrix

			PRODUCT															
			P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8	P-9	P-10	P-11	P-12	P-13	P-14	P-15	P-16
PROCESS	SUB-ASSEMBLY 1	W-1	√	√	√	√	√	√	√	√	√						√	
		W-2	√	√	√	√	√	√	√	√	√							
		W-3	√	√	√	√	√	√	√	√	√							
		W-4																
		W-5																√
		W-6																√
		W-7										√	√	√	√	√		√
		W-8										√	√	√	√	√		
		W-9										√	√	√	√	√		
		W-10										√	√	√	√	√		
	PART 1	S-1				√	√	√	√	√		√	√	√	√		√	
		S-2				√	√	√	√	√		√	√	√	√		√	
		S-3				√	√	√	√	√		√	√	√	√		√	
		S-4	√	√	√	√	√	√	√	√		√	√	√	√		√	
	SUB-ASSEMBLY 2	R-1	√	√	√		√	√	√	√							√	
		R-2					√	√	√	√							√	
		R-3	√	√	√	√	√	√	√									
		R-4								√	√				√	√	√	√
		R-5								√	√				√	√	√	√
		R-6	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
		R-7	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		R-8	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
		R-9	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√
	ASSEMBLY	A-1																√
		A-2	√	√	√													
		A-3	√	√	√													
		A-4				√	√	√	√	√	√	√	√	√	√	√	√	
		A-5				√	√	√	√	√	√	√	√	√	√	√	√	
		A-6																√
		A-7																√
		A-8																√
		A-9	√	√	√	√	√											
		A-10						√	√	√	√	√	√	√	√	√	√	
		A-11	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Now since mapping will begin from customer end, the customer factory icon (from standard process icons of VSM) is used to note down the customer demand per month, customer demand per day, Takt time and Lead time of product/s. The next step is to draw the basic production processes with the use of various standard VSM symbols. To indicate the process, a process box is used.

The data to be recorded in the process box is:

Cycle Time (C/T) which shows the machine on to machine on the time of a process. The time an operator takes to finish the process before starting it again.

Changeover Time (C/O) is when a machine switches over from one product time to another a change is made in the machine setting. *No. of Shifts* is the number of shifts per day and

No. of Operators is the number of operators working on that process.

The amount of inventory is recorded between two workstations i.e. to be processed and processing jobs of a workstation. As the mapping approaches the supplier side the raw material inventory in the factory is recorded. The Production Planning and Control Department monitors the Customer end, Supplier end, and the manufacturing activities in the factory. A current state map, basically with a high level description of information and manufacturing processes, having deep insights into the present situation is developed for Product 1,2 and 3 in combine (see figure 4). It offers a clear view on current process so that improvement opportunities can be explored by visualizing problems and wastes. This map provides holistic view of information-process flow which otherwise not visible, it also helps in visualizing the effect of improvements on overall state of map. The problems or gaps need to be identified and on current state by bursts, this provides a roadmap and guidance for the future state map by filling up the gap areas and eliminating obstacles that prevent flow.

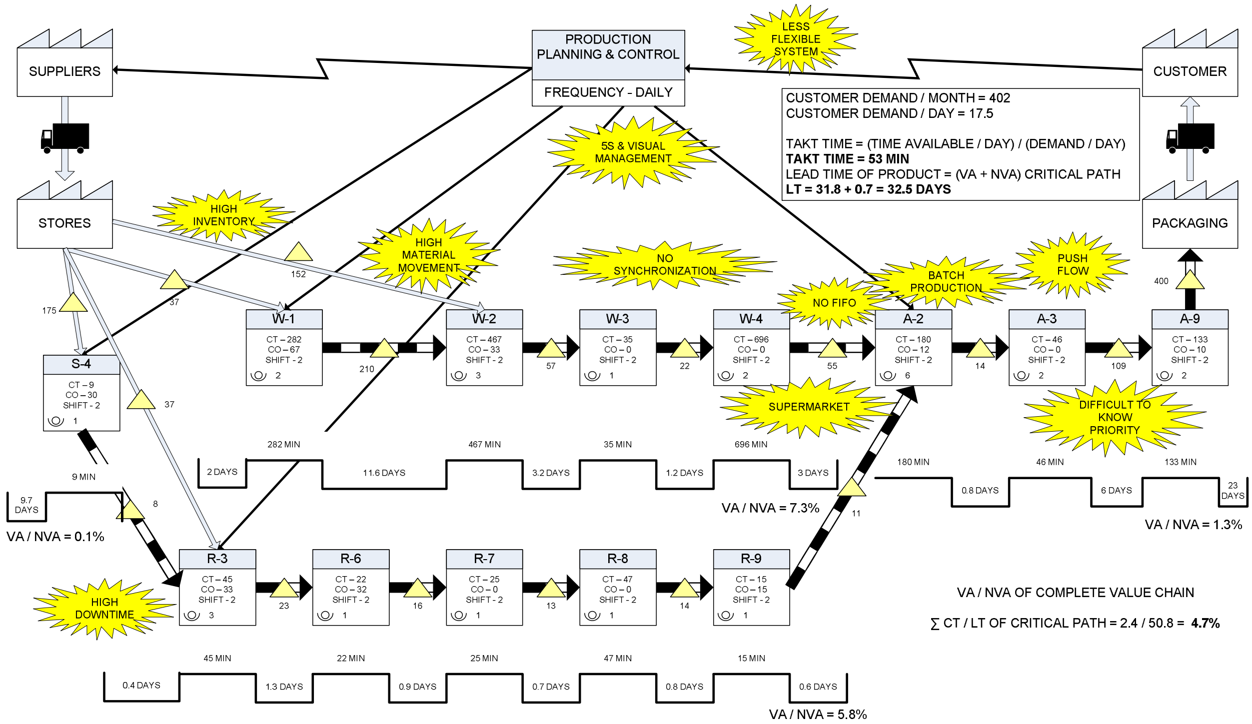

Figure 4. Current state map

5. Analysis of current state map to develop future state

5.1 *Analysis and brainstorming*

Once the current state map was developed, brainstorming session was conducted to come up with ideas to reach to future state map. Brainstorming is a popular and effective tool to generate creative solutions by looking at the problem in novel ways and utilizing the diverse experience of all team members involved [31]. It enables deep diving to explore root causes and increases involvement of team members to share ideas with better solutions. More specifically, it takes stakeholders into account to reach to the solution, which generally is more feasible and sustainable in nature. Additionally, active participation encourages the specific role to play by each team member, which creates positive and rewarding environment for problem solving and leads to improved bonding among them [5], [31].

After identifying where muda was located throughout the system, it is important to identify the root cause of the muda and reduce or remove it. According to the analysis of current state map, following observations were made:

- ***Less flexibility of the overall system:*** Since the company caters to customized requirements, it disturbs the original production method. This causes a delay in delivery of the products at a certain time which shows the incapability of the system. Information is being transferred to many points in value stream, which further creates problems like synchronization, setting priority, FIFO, etc.
- ***High inventory:*** During our door to door mapping, we have found a high accumulation of inventory at places on the shop floor. 23 days of finished goods inventory lying at dispatch center and more than 10 days of inventory of components lying at very start of value stream. This high inventory not only restricts space but also locks the money involved in production due to material waiting which is also a waste.

- ***Poor 5S and Visual management:*** 5S denotes *Sort*: remove unnecessary items, eliminate obstacles, evaluate necessary items, *Set in order*: easy availability of items preventing loss of time, smooth workflow, *Shine*: workplace should be clean, *Standardize*: everything according to standards, orderliness, *Sustain*: to keep everything in working order. Basic visual markings for high, low inventory, FIFO lane, order quantity, target, and backlog were missing.
- ***High material movement:*** Due to the high quantity of orders, the company outsources certain sub- assemblies which lead to a very complicated network of material movement. Keeping track of the activities, like transportation, rework etc. increases the actual manufacturing time. Another reason was process layout and specialized machines, which restricted the single piece flow.
- ***No synchronization in flow:*** Due to improper communication, unavailability of material, difference in process timings between the parallel paths there exists no proper synchronization. Another reason for this is *Push flow*, which means the process produces something regardless of the actual needs of the downstream customer process and pushes it ahead hence adds up the inventory for the next workstation.
- ***No FIFO:*** "first in first out" of material/components was not followed throughout the shop floor. Most times the components ware picked up randomly.
- ***Batch production at certain places:*** Unnecessary batching of components due lack of single piece flow increases the inventory between processes restricting space. This also increases the batch size to trade off high setting time.
- ***Difficulty to know priority:*** Lack of identification makes it difficult to identify the sequence hence priorities can't be determined. Most of the times, it is verbally communicated which leads to miscommunication causing disruption in flow.
- ***High downtime at certain workstations:*** Machine breakdowns occurs due to the following reasons, i.e. over-running machine's capability, improper maintenance, asking the untrained person to operate the machine, rough use by operator etc. Breakdowns at certain machines create bottlenecks in the process halting the entire flow.

The above problem leads to high accumulation of inventory worth 66.4 Million INR, high lead time of 52.4 days and very low VA/NVA ratio of 4.7%. While mapping future state map, the improvements were considered according to above key areas.

5.2 Future state mapping

The purpose of value stream mapping is to highlight sources of waste and eliminate them by the implementation of a future state value stream that can become a reality within a short period of time. The goal is to build a chain of production where the individual processes are linked to their customers either by continuous flow or pull and each process gets as close as possible to producing only what its customer needs when they need it. The future state map is a depicted in figure 5, after working out the inventory values and other changes in the flow as per the answers to the key questions.

Key questions to be asked for the future state map:

- What is the Takt time?
- Will you build finished goods supermarket from which the customer pulls? The answer to this question depends on various factors such as customer buying patterns, the reliability of processes and the characteristics of the products.
- Where can you use continuous flow processing?
- Where will you need to use supermarket pull systems in order to control the production of upstream processes?
- At what single point in the production chain (the 'pacemaker') will u schedule production?
- How will you level the production mix at the pacemaker process?
- What increment of work will you consistently release and take away at the pacemaker process?
- What process improvements will be necessary for the value stream to flow as the future state design specifies it?

The main practices that were included in the future state map were:

- ***Pull system*** This describes the extent to which production is driven by customer demand [9], in which following process withdraws (pull) parts from the preceding process. The benefit is operators gain an accurate knowledge of timing and quantity required. It removes any excess or waste of resources in term of labour or machine capacity.

- ***FIFO*** This ensures that when a product is being produced it should be consumed by the next workstation in the sequence in which it is handed over by the previous workstation. FIFO builds up inventory but it always a controlled inventory. The maximum and minimum limit in a FIFO lane was predetermined. Once the max limit reaches the supplier gets an indication to stop producing.

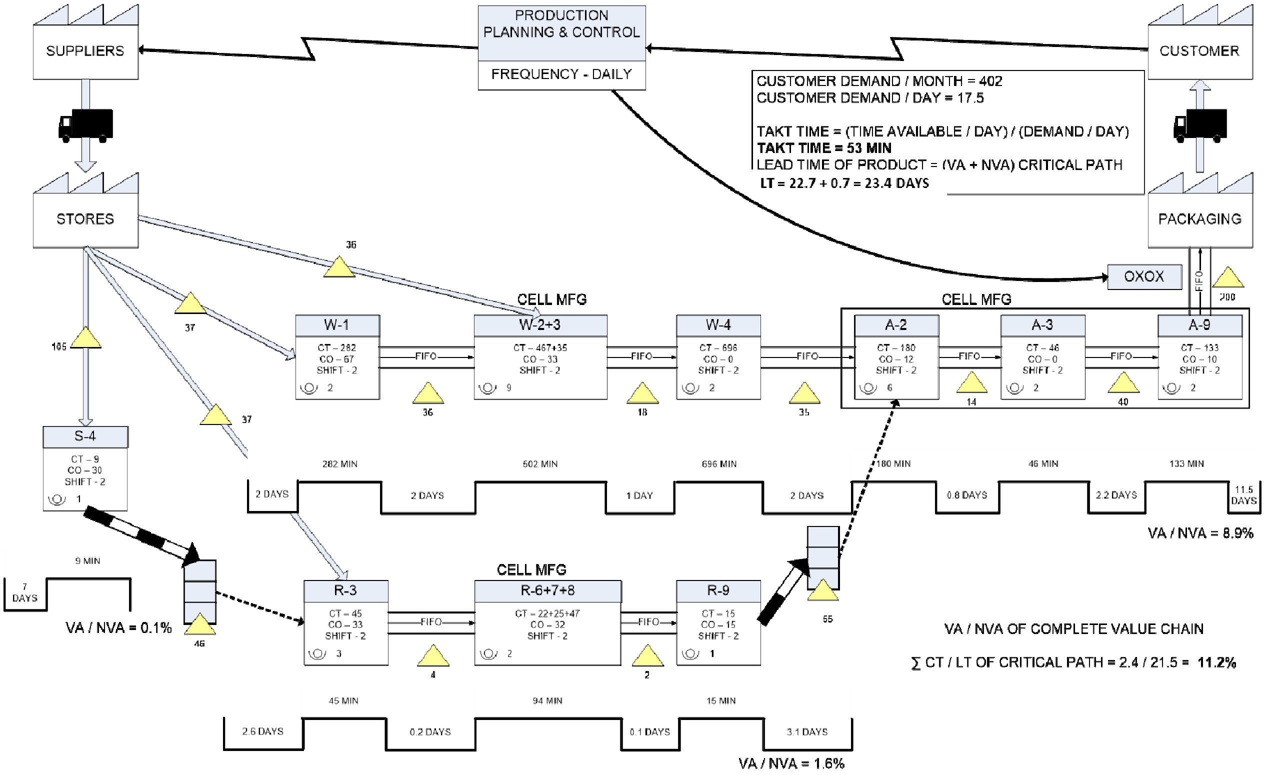

Figure 5. Future state map

- ***Supermarket*** There are places in value stream where continuous flow is not possible and batching is necessary, thus by supermarket system batching can be done in a regulated amount. A ''supermarket'' is nothing more than a buffer or storage area located at the end of the production process for products that are ready to be shipped [1], this can also be extended to intermediate processes. The customer pulls whatever is needed and it is replenished by the supplier. A production kanban triggers production of parts, while a withdrawal kanban is a shopping list that instructs a material handler to get and transfer parts.
- ***Safety Stock*** This is generally used to protect against sudden fluctuations in customer orders or machine breakdown. By monitoring and analyzing the distribution database the particulars of the safety stock were determined.

While making the future state map it was observed that at some places, due to high changeover times batch production was mandatory unless and until by providing optimum safety stock option, it was ensured that the availability of sub-assembly would be as per the requirement without disturbing the setting of the upstream process.

- ***Milk Run*** It is a system where material handler provides frequently variety of components in small quantities directly to workstation based on Kanban signals, during one course several workstations are served [12]. The major benefit of this system is to reduce the level of inventories at the workplaces and prevent operators from leaving workplaces to bring the parts. Milk Run system implemented to ensure that the delivery of raw material would be done as per the daily requirement.

- ***Process improvement*** It is a small and effective improvements toward reducing the value added time. This effectively optimizes work hours of labor and production rate of the machine. Current state map pointing to the small percentage of VA in total time, hence it becomes necessary to focus on reducing NVA first. Process improvements give direct reduction in cost and encapsulates tangible benefits. Simplification of product and processes for manufacturability significantly reduced process time.

The endeavour of future state map is the output of the proposed changes based on the gaps identified in the current state map. Ref. [16] emphasized that suppliers must acts as the seamless extension of the focal organization. Hence, it was advised to involve suppliers in the implementation in a later stage to regulate deliveries as per proposed process.

6. Results and discussions

Observations of the current state map and analysis of the critical path revealed the opportunity of establishing pacemaker process. In current research, team has decided the final assembly as the pacemaker process. By using the supermarket pull systems, the scheduling needs to be done only at one point in your door to door value stream. This point is called as the ‘Pacemaker Process’, because how the production is controlled by this process sets the pace for the further downstream processes. Assembly is the juncture which is the final customer in the manufacturing processes. By monitoring this point, the assembly requirements from upstream would be demanded in a predetermined manner. This will regulate the working of the entire plant for this product family. Thus, the assembly being the pacemaker process is selected as the target area for improvement. Considering the fact that 17 quantities are produced on assembly on a daily basis currently, instead of producing it in batches, if a single piece flow is implemented the production will take place as per the takt time. Thus the delay or excessive inventory dumped upon the next workstation will be completely eliminated.

The results of the future state map shows that the average lead time reduced to the 21.5 days from 52.4 days. In another word, reduction of lead time by 59%. This can be achieved by reduced inventory levels of components and finished product. Future state significantly reduces the inventory costs by 61%, which is 4.31 Crore INR. Table 4 summarizes the results achieved through VSM. Although, there are numerous opportunities for the further improvements including 5S and visual management on the shop floor, implementation of Andon and Jidoka system for transparent issue resolving.

Table 4. Comparing results between current-state map and future-state map

Comparing items	Current state	Future state	Improvement ratio
Communication points	4	1	-75%
Lead time, days	52.4	21.5	-59%
VA/NVA ratio, %	4.70%	11.2%	138%
Inventory (Million INR)	66.4	26.1	-61%

7. Conclusions

The case study presented in this paper intends to give lean practitioners a reference for implementing lean systems in discrete manufacturing operations. In this case study, the VSM team began the process by identifying the product family, based on its P-R and P-Q analysis. Next, a process at a glance and a current value-stream map were created. A future-state value stream map was then created which served as a goal for future lean activities. The team asked the questions to identify the root cause of the issues that kept the company from moving towards the future state. Various lean tools/practices were then identified as solutions to overcome these hurdles and achieve greater process efficiency.

Implementing lean manufacturing can increase the competitiveness of a company in the global arena. In this case study, Company ABC reduced their lead times while at the same time improving the VA/NVA of their products after lean implementation. Communication was greatly simplified when a design change occurred. The manager only needs to inform at a pacemaker about the production plan, rather than informing to complete value stream as in the previous system.

However, it is necessary to reflect on the main limitations of this research methodology from an implementation perspective. First, this research assumed that the layout will continue to be a process layout and due to bulky and specialized machines, perfect single piece flow cannot be achieved. Secondly, the case study does not consider an automation of processes and material handling system due to management’s decision of not investing for same. Third, the case does not consider any long-term strategies, specifically pertaining to the high degree of change in product design. Finally, use of the flexibility of manpower is not being considered fully in view of strong unionization of the plant. Therefore, implementation of lean production needs to be done over many years in most cases, to bring positive cultural change and acceptance.

Future research directions includes extension of the VSM methodology to include other product families, possibly encompassing supplier considerations. Also, the major area for further improvement could be change in layout from process to single piece by linking all processes. The success of the pilot VSM in the Company ABC to adopt the lean concept as an ongoing business strategy. The management was interested in using it to enhance the overall competitiveness of their business. Company ABC now intends to extend VSM and lean strategies to other product families. It is expected that, eventually, lean manufacturing will be implemented throughout the company.

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