Application of value stream mapping using simulation tool in manufacturing assemble line: A case study

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Abstract. Value stream mapping is one of the most convenient graphic tools in the manufacturing industry to eliminate wastes. This study has been carried out for the heat sink part assembly line of a manufacturing unit. The basic objective was to employ computational tools for carrying out value stream mapping and to make improvements. In the first stage, value stream mapping was done for the existing assemble line with details such as cycle time, setup time, number of employees, etc., to identify bottlenecks. Future value stream mapping was carried out using a software tool. Simulation is employed for identifying the real-time production bottlenecks; this in turn leads to improvement in productivity. This proposed method can be implemented for any manufacturing industry to eliminate non-value-added activities (NVA). The study demonstrates that the use of appropriate computational tools ensure standard methodology for a complex problem as well as produces quick results.

1. Introduction
To be competitive in the national and global markets, manufacturing organizations have to adopt and implement better strategies to be successful. The current industrial revolution is moving ahead with rapid progress in technology transfer along with better practices to eliminate non-value added activities in the manufacturing sector. It is the larger consumer of natural resources, this will lead to a severe impact on the industrial sector. It poses a severe effect on the growth of developing nations such as India, China, Brazil, and the like. In the Indian economy, the manufacturing sector is one of the main contributors to economic development. But Indian manufacturing firms are not coping up with the global market in competition and growth due to obsolete technology and financial constraints. This can be overcome by less investment, better management strategies, computational tools, and techniques in the manufacturing sector. Therefore, there is a need to fill the gap in the manufacturing sector through computational tools and lean manufacturing principles with less investment for
enhancing economic performance and competitiveness. A lean manufacturing system is an effective
 technique in identifying and eliminating different wastes for improving productivity by reducing lead
time in production.
 Manufacturing layout plays a key role, it incorporated with numerous work stations and workflow
path; to carry a raw material till a finished good is produced from it. Each operation is performed as
per schedule and sequencing to meet production volume; each entity is interdependent on the other for
completing a required task in a given time. Shortage of inventory, unavailability of machine tools, and
breakdown of machines causes a delay in meeting the production rate. Improper layout design,
unidentified items, and unnecessary flow of material create fatigue to the operator. This eventually
results in a slower production rate. VSM analyzes the manufacturing processes from the beginning to
the completion of tasks with the help of available facility, the flow of material, people, products, and
information. A visual representation map can be drawn based on this. Value stream mapping (VSM) is
an efficient tool to make the entire stream valuable by eliminating the non-value added activities. It
describes the value map which is a collection of value-added and non-value-added activities. This map
comprises every single process involved in the material and information flow. Based on the present
data, a future state map is drawn to show how things would work to attain competitive advantage for a
firm. Due to severe competition, firms are working for achieving minimal lead time, lower production
costs, and greater customer satisfaction. In the present work, lean techniques along with computational
tools are successfully used to reduce lead time in a heat sink part assembly line. Tecnomatix Plant
Simulation software is used in the present study to capture non-value added activities in the
manufacturing unit.

2. Literature survey
Lean manufacturing, pioneered by the Toyota Motor company, has become very popular among
manufacturing organizations around the world, to reduce waste. Value stream mapping (VSM) is
a lean management method for analyzing the current state and designing a future state for the series of
events that take a product or service from its beginning through to the customer. Several research
studies have been carried out to analyze the effect of VSM on productivity. Life usage monitoring
system (LUMS), which is one of the best methods to identify the component wear out, fatigue failure,
and damages of aerospace components [1]. LUMS method uses lean principles to make the process
scheduled, process planning and controlling. It was concluded that the LUMS method can be used to
find failure mechanisms in engine parts (Blades, Discs). Lean startup methodology (LSM) focuses on
failures in the business area and agility (market response) [2]. It also helps an entrepreneur in
identifying the different causes of business failure. It interpreted that LMS gives a clear view of the
improvement in their business.
 Manufacturing strategies have explored procedure on knowledge creation and lean performance[3].
This method helps the management in creating knowledge on lean indicators in explicit and tacit ways.
It played a major role in lean practice and it has been used as a prerequisite for lean adoption.
Further, it suggested that the top management should have more awareness of knowledge creation and
its performance to improve the performance level. A manufacturing sector has chosen to discuss and
assess the work in the process in the manufacturing line with the help of a mapping tool[4]. It was
found that the mapping tool plays a major role in identifying, analyzing, and evaluate certain non-
value added activities in a flow line and hence improves productivity.
 VSM helps in reducing different non-value-added activities like process variation, product defect
identification, machine variability, etc [5]. It represents the whole process of the assembly line
byographical method whereas VSMII shows the process mapping for a product family i.e. group of
product which has gone through a similar process and with the help of variability index, processing
time can be calculated.
 VSM tool found reduces the wastes and increases the efficiency of the production line[6]. They
interpreted 5S, kaizen, and kanban are the most important tools in a manufacturing firm to eliminate
wastes. Companies require improvement in various factors such as production lead time, customer
service, etc to survive in the competitive world [7]. This paper details how to draw the value stream mapping by collecting relevant data about the process flow and identify the different non-value-added activities and suggest the future value stream map to eliminate different wastes and putting significant effort in improving the production efficiency. VSM can be implemented for both manufacturing and service sectors [8]. The tool explores different Muda, which is a serious issue in the organization which affects the production level tremendously. By representing the future mapping graphically, improvements in lead time, overproductions can be done effectively. Therefore, the authors declared that value stream mapping is the best tool that eliminates different wastes. Value stream mapping is the fundamental tool of lean practice which has been proved efficient in reducing the different mudas. Finally, it was proposed that value stream mapping is one of the best tools of the Toyota production system which can be implemented successfully for the organization to reduce or eliminate the wastes.

A series of different scenarios of the present and future map to and detect various wastes that can be eliminated and the flow line can be made smoother. Interestingly, it has shown that VSM can help in the ergonomic design of work stations and make the production line streamlined [9,10,11]. Hence, productivity also can be improved. An application of value stream mapping in the manufacturing sector and investigated the main difficulties and limitations in drawing the current value map [12]. Finally, it tried to explain that rather than benefits in the implementation of value stream mapping tools try to get an exposure on basic knowledge in drawing in the value map and also its limitation.

Further, computational tools are very important for lean manufacturing systems. The combined effect of lean practice with simulation software makes the system feasible. Many research works discussed various simulation software such as simul8, ARENA, Discrete event simulation (DES), Tecnomatix simulation (TX) have been integrated with lean with to improve productivity and material flow can be optimized by implementing optimized simulation techniques[14]. The evaluation of present and future value maps based on discrete simulation process and control feedback also be an essential element to help in preventing deviations in the production line. Finally, it interpreted that the simulation software is particularly suitable for medium and high volume production industry. An earthmoving bucket manufacturing industry for the case study [13]. Collected data such as set up time, work in the process as (WIP), cycle time at the individual workstation, and identified the wastes. Value stream mapping for the present process can be drawn and by inputting the value to the arena software for model creation, the simulation will be done and wastes are identified virtually, analyze the process.

As can be observed, frameworks to extend VSM to assess shop floor performance have been proposed by many. However, there is a need to incorporate better strategies for enhancing productivity with optimal utilization of resources. A comprehensive application of VSM through simulation tool highlights the different scenarios for optimizing the layout before implementing the proposed plans and not only serve as a tool to identify and eliminate waste in any activity that does not add value to the final product in the assembly process. With this objective, a case study has been carried out in a heat sink part manufacturing assembly line to capture the benefits of VSM along with simulation tools. Simulation technique along with lean manufacturing principles in the manufacturing process gives valuable insights to compare the present value stream mapping (PVSM) to identify the value-added and non-value-added activity and propose future value stream mapping (FVSM) to eliminate the wastes.

3. Methodology
The VSM methodology and Tecnomatix plant simulation software are adopted in the present study. The systems approach will help to provide a holistic view during the project. A combination of the case study and action research has been used as the research method. Initially, the research will start with a case study to build a thorough understanding of the organization and its processes. After this has been achieved the focus will be altered to improving the process while observing it. This means that the research method will be changed into action research. The important steps to getting started with the value stream mapping process which has been followed in this work are shown in Figure.
The following wastages were identified in the current of the heat sink part assembly line of a manufacturing unit:

- It has bottlenecks such as stage inspection in the manufacturing line which leads to waiting time and delays in production order.
- There will be waiting time in the final (workstation) inspection stage.
- Excess stock in the inventory

The well-reputed manufacturing industry was selected for the case study. The first step is to visit the company assembly line to get a clear idea about the manufacturing process in the assembly line. The main objective of the VSM tool is to expose and reduce the time and price which is not adding any value to the product as much as possible. By implementing VSM with the Kanban tool, the company can reduce its WIP by converting the push systems into a pull system. Current data was collected and identify the different non-value added activities (NVA) such as excessive inventory level, huge production lead time, overproduction, rework, scrap, set up time, mismanagement of resources, errors in production layout, etc. VSM is the only process that includes both flows in current and future state maps and helps establish a relation between them. The initial stages of VSM consist of mapping the current state of the manufacturing plant. The current state is studied to identify wastes and bottleneck processes present in the process. Appropriate solutions are proposed to eliminate wastes, based on which a future state map is created[14].

It is very essential to understand the flow of material and information along with the machine stations involved with the process. Data collection should start with the “end customer” and walk the process backward. Information such as non-value-added time (time which does not contribute to final product), changeover time (time to change tool or machine time, etc.), amount of WIP(Work-In-Process), a number of operators at each station, standard set up for each operation, inspection or
testing time and the like are collected for evaluating waste. It is also beneficial to calculate Takt time for comparison to the actual process time once the VSM is complete.

It has been observed from the literature there are various wastes identified in the manufacturing firm that reduce productivity like over-processing, unwanted or excess inventory, defects (scrap/rework), waiting (unnecessary delay), unnecessary motion or movement, and the like.

A simulation study is not only restricted to optimize the process, rather it gives an immense idea to the manager of the company a clear knowledge of lean implementation and also LM elements effects on the performance of the organization. This software can experiment on the various process parameters in the organization such as the design of the layout, allocation of resources, and the like, which helps in minimizing the production throughput and cost.

The study of the current layout is carried out as follows: In the present scenario, there are 7 workstations in the heat sink part assembly line with one manpower at each work station. There was a visual inspection between the station 3rd and 4th between which consume 12 seconds for inspection of each part which leads to waiting time in the line. There is a need to improve productivity by eliminating visual or stage inspection; because the number of defects identified from the production histories is 4 out of 1000 parts produced in the series if workstations kept before the visual inspection, it leads to an increase in production time, waiting time, blocked time for next operation and interruption for smooth production. It was observed that at end of the assembly line there is a final inspection that will cover the operation performed at the 4th work station and it consuming more time. Therefore, there is a need to improve the typical manufacturing assembly line with simulation techniques and with different scenarios to enhance its performance. Hence a proposed model is developed to eliminate the state inspection in the line and reduce the workforce to 30% with the same production order (output).

The current value map is used for developing the model with process parameters captured from the assembly line for each work station. Information such as setup time, number of operators, machine arrangement, cycle time, and change over time were collected in the workstation are noted in table 1.

| Sl.No | No of operators at each work station | Operation involved | Cycle time(sec) | Changeover time(sect) |
|-------|-------------------------------------|--------------------|-----------------|----------------------|
| 1     | 1                                   | Bolt pressing      | 10.28           | 0.93                 |
| 2     | 1                                   | Diode pressing     | 10.28           | 0.28                 |
| 3     | 1                                   | Diode Testing      | 12              | 0.22                 |
| 4     | 1                                   | Visual inspection  | 12              | 2                    |
| 5     | 1                                   | Riveting & flaring | 16.58           | 6.58                 |
| 6     | 1                                   | Crimping & welding | 14.40           | 4.40                 |
| 7     | 1                                   | Final inspection   | 23.07           | 4.2                  |

A snapshot of the simulation model for the current VSM is shown in figure 2. The entities of different machines were identified from the manager class library and are built-in the “Simulation world”. The existing plant was abstracted by placing the different workstations as per the distance allocated and labor was imported to each workstation as per the table 1. For each workstation, the details of setup time, processing time, recovery time, etc, were feed in the associated box. The sequence of operations for processing heat sink part assembly is established in the material flow line as shown in figure 3. Some of the bottlenecks observed in the manufacturing line are visual or stage inspection between the stations, unnecessary labor allocated in stage inspection which leads to labor cost, and also waiting time in the final inspection. With the help of simulation software build an efficient layout and set an optimal number of the operator.
The current value map revealed many non-value-added wastes in the assembly line. To reduce this waste and increase productivity, different scenarios are analyzed and it has been proposed to eliminate stage inspection to reduce the cycle time and also suggested implementing them with the automated inspection at the final inspection stage and the results were quite encouraging. Tecnomatix Plant Simulation (TX) software is proved as an improvement tool in yielding the results in seconds with minimum cost to real-life implementation and testing. It explores the dynamic flow effects hidden in the static value chain. The goal is not only to eliminate such waste but to ensure the manufacture of product as per the customer's demand or requirement as quickly as possible and at the lowest cost. The proposed plant layout was abstracted by placing the different workstations to optimize the process parameters and the layout for enhancing productivity as per table 2. The proposed layout can be visualized by future value stream mapping as shown in figure 4 and simulating the proposed layout to estimate throughput as shown in figure 5.
Table 2: Details of operations carried out in future value map

| Sl. No | No of persons | Operation involved          | Cycle time (sec) | Changeover time |
|--------|---------------|-----------------------------|------------------|-----------------|
| 1      | 1             | Bolt pressing               | 10               | 0.65            |
| 2      | 1             | Diode pressing              | 12               | 2               |
| 3      | 1             | Diode Testing               | 11               | 0.78            |
| 4      | 1             | Riveting & flaring          | 12.88            | 0.12            |
| 5      | 1             | Crimping & welding          | 13               | 0.91            |
| 6      | 1             | Final inspection            | 24               | 0.93            |

Figure 4: Future value map for heat sink assembly line

The following figure 5 shows the simulation model future value map

Figure 5: Future layout of the heat sink assembly line
4. Results and Discussion
Most of the literature survey focussed on LM elements. From the literature survey, it has been found that simulation tools can be utilized along with value stream mapping. This paper attempted that integrating a software simulation tool with conventional VSM can overcome the various non-value added activities in a manufacturing assembly line of a selected organization. These simulation model proved for the shop floor managers and engineers practically observe and feel how the future process (or) layout before implementing the actual design of lean manufacturing system (LMS) it makes the production process more flexible. The transition from the conventional method to the digital method using Tecnomatix plant simulation tools gives concrete results for the organization. by comparing the present and future data; it has been clear that cycle time has been reduced from 98.61 seconds to 82.88 seconds and workforce also reduced from 7 to 6.

5. Conclusion
The need for the present study was to develop a value stream map for the heat sink part assembly line to identify and eliminate waste which is any activity that does not add value to the final product in the assembly process. It is also aimed at reducing lead time and increasing the throughput rate of parts. VSM is a continuous improvement process; we must keep on changing the future state into the current state that will not end during our life. VSM has been proven to be a greatly useful tool to eliminate some waste in a cycle and find there is more waste for us to eliminate in the next cycle, during which lean becomes a habit or culture. The technique of lean tool can be applied to every situation in a company by finding out what customer wants and eliminating waste. The idea is to create a culture in which people at various levels of an organization are continuously improving their products every day & in every way. Identified the bottlenecks such as cycle time, unnecessary inventory, stage inspection between the stations, and downtime & layout design. Hence, proposed a new method with the help of a future value map with the support of simulation software to get quick results. In the proposed layout the workforce is reduced from 7 to 6 numbers by redesigning the layout. Cycle time is reduced from 98.61 seconds to 82.88 seconds and hence the productivity will be increased by 15%. There is a need to set up automated inspection (buffer) to avoid piling up inventory at the final inspection.

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