Jurnal Kejuruteraan 33(4) 2021: 1007-1018
https://doi.org/10.17576/jkukm-2021-33(4)-22

Performance Improvement through Value Stream Mapping – A Manufacturing Case Study

Salman Abubakar Bugvi[a*], Khurram Hameed[a], M. Fawad Jamil[a], Ali Irfan[a], Shahid Murtaza[a], Muhammad Qaiser[a] & Muhammad Bilal[a]

[a]Department of Mechanical Engineering,
The University of Lahore, Lahore, Pakistan

**Corresponding author: salman.bugvi@me.uol.edu.pk*

Received 11 February 2021, Received in revised form 26 March 2021
Accepted 20 April 2021, Available online 30 November 2021

ABSTRACT

The successfulness of Value Stream Mapping (VSM) as a tool for taking a snapshot of the production flow efficiency is well established. The development of a large-scale visual map of processes and their interactions is beneficial for problem analysis and subsequent solution. Through VSM, managers gain a deeper understanding of the organization processes carried out in coordination with people in a system approach. A case study was conducted at a Small and Medium Enterprise (SME) in Pakistan which manufactures ceiling fan winding machines. The aim of this study was to explore the possibilities of shortening the lead-time, waste and highlight important strategies, steps which could be undertaken by management for improvement in productivity, cost and quality. The study maps the organization systematically through the use of VSM. The Lean Implementation Techniques (LIT) steps were followed with identification of value stream process, lean metrics, mapping of current state and proposing an improved future state value stream map. The intervention suggested is layout modification by reducing 7 stations to 6 stations and streamlining the operations. The layout modification results in lower defects, controlling overproduction, managing inventory buffers from a linear approach to an optimized level. This also resulted in reduction of processing time of each unit by around 19 % and the production lead time of 100 units by around 21%. This study through VSM proposes improvement by enforcing pull system, supplier relations, modifying layout and production processes, Just in Time (JIT) delivery of materials and parts, scheduling transport resources efficiently and reducing inventory buffers.

Keywords: Lean manufacturing; Value Stream Mapping (VSM); production flow; waste; productivity

INTRODUCTION

Efficiency and competitiveness of the manufacturing company are the two essential challenges faced in the market. Efficiency demands an inward focus with the aim to improve and do more with less. Market competitiveness demands comparison with other entities to provide better product or service. Adoption of Lean Manufacturing principles gives the advantage of higher efficiency and competitiveness to the manufacturing firm (Kariuki & Mburu 2013). Many manufacturing companies are continuously competing to upgrade their strategy and reduce problems in manufacturing (Corbett & Van Wassenhove 1993). Products have to be produced at a lower cost, with better productivity and high quality. The present phenomenon of lower product life cycle, advance technology, global supply chain, complexity of products, mass customization has placed increasing demands on business (Groover 2020). Lean Manufacturing is also being used with innovation and flexibility in these scenarios. A number of methods or tools to improve efficiency and productivity are available in Lean Manufacturing literature (Dresch, Veit, de Lima, Lacerda & Collatto 2019; Feld 2000). Value Stream Mapping and its variants are a well-documented and established technique (Lasa, Laburu & de Castro Vila 2008). It can not only be used in manufacturing but other sectors as well (Shou, Wang, Wu, Wang & Chong 2017). In some cases, it becomes essential to opt for Lean Manufacturing just to survive in the market especially for small and medium enterprises (SMEs) (Achanga, Shehab, Roy & Nelder 2006). The concept is to improve the business responsiveness and efficiency through waste reduction, product improvement and minimization of cost (Rajenthirakumar & Shankar 2011).

Each business with its products, processes, culture, management, organization and inputs is a unique entity. These manufacturing organizations with their points of differentiation react differently under Lean Manufacturing operations. It is an interesting proposition to study a case company and prepare a visual map for analysis. The objective of this case study at organization under consideration was to find types of production wastes and determine the details of manufacturing processes through VSM. The study identifies the root causes of waste and compares the lead time of product before and after the production process improvement (Seth & Gupta 2005). The following questions were investigated in the present study:

1. How can Lean Manufacturing framework be applied to reduce the wastes in the product?
2. What are reasons of waste in the case organization?
3. How can lead time of the product be decreased?

The VSM was performed on the manufacturing process flow of a Pakistani SME. The current state of the case organization was mapped with the identification of wastes, areas of improvements and bottlenecks (Singh, Garg & Sharma 2011). A better future state is proposed for the case organization, which will give it competitive advantage, financial stability and quality (Rother & Shook 2003). The techniques and principles of Lean Manufacturing and Value Stream Mapping were integrated at a manufacturing factory with viable recommendations for implementation (Zahraee, Hashemi, Abdi, Shahpanah & Rohani 2014).

A number of studies have been conducted which make use of the VSM technique in Manufacturing (Jasti & Sharma 2014; Khalili, Ismail & Sulong 2020). Discrete Manufacturing company has been moved to a better future state by lowering the lead time, inventory and value added and non-value added ratio (VA/NVA) (Chaple & Narkhede 2017). The productivity, performance and quality of process in a SME were improved by the use of Lean – Kaizen technique after conducting a value stream analysis (S. Kumar, Dhingra & Singh 2018).

Lean Manufacturing is a continuous and evolving process in modern manufacturing units. The unique intervention, application and problem-solving approach at the case organization can be improved and built upon by other organizations.

LITERATURE REVIEW

LEAN MANUFACTURING

Lean manufacturing is a precise method to improve industrial operations. The purpose of this technique is to make improvements and reduce waste continuously (Negrão, Godinho Filho & Marodin 2017). The productivity of the machine and manufacturing unit is increased by varying the combinations of input, process and output to give better and efficient product for customer (Palcic, Ojstersek & Buchmeister 2018). The Japanese car manufacturing companies introduced JIT Manufacturing to further complement Lean Manufacturing. This concept is being applied extensively in many companies and departments (Bhushan, Aserkar, Kumar & Seetharaman 2017; Dowlatshahi & Taham 2009). The aim of Lean Manufacturing is to reduce waste and cost, while improving quality and productivity at strategic, tactical and operational levels (Iuga & Kifor 2013).

One of the aims of Lean Manufacturing is to view the activity from the customer perspective and product requirement (Saad et al. 2006) and reduce the less useful and costly activities. The basic view of Lean Manufacturing is to remove non value-added activities from business. The Japanese called the waste "Muda". Waste is the root cause of problems and if waste is reduced, production quality will improve. Seven types of the common wastes identified in Lean Manufacturing (Chahal, Grover, Kumar & Pardeep 2017; Elnamrouty & Abushaaban 2013) are exhibited in Figure 1.

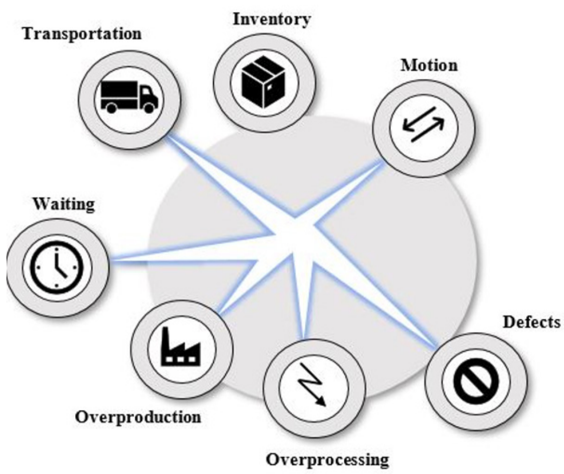

FIGURE 1. Seven types of waste (Rother & Shook 2003)

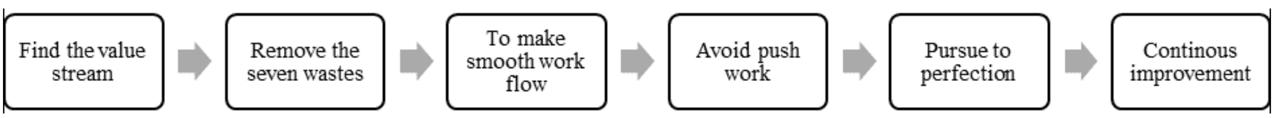

FIGURE 2. Lean Manufacturing Principles

Lean Manufacturing is a continuous improvement to remove waste and increase the Value Added in both goods and service value to the customers Amrina & Lubis, 2017. The purpose is to adopt a systematic approach to find and eliminate the waste. In Lean Manufacturing approach, there are three distinct activities that have been identified.

1. Activities that do not add value and these can be reduced or eliminated.
2. Some activities that do not add value but cannot be replaced or eliminated.
3. Activities that provide added value (Chen & Cox 2012).

The defects or wastes identified through VSM are present in the manufacturing chain. The manufacturing chain links the production process, including the activities involved at each point, information being exchanged, natural resources being turned into usable products, human capital and other components going into the finished product or service (Chopra, Meindl & Kalra 2013). The six manufacturing drivers defined are as follows;

Facilities are the locations in supply chain network where product is being stored and assembled. There are two main types of facilities which include production sites and stores.

Inventory contains all the raw materials, work in process, and final product in the supply chain. Excessive inventory can increase the cost of product and affects the finances of the company.

Transportation is used to move the product from one point to the other point of the manufacturing chain. Transportation is done manually or through machines such as rail ways, trucks, and ships. The inputs, work in process and outputs have to be handled within the manufacturing factory through manpower, conveyor belts, fork lifts or other appropriate means.

Information consists of data and analysis on products, production, transport, cost levels and consumers in the chain.

Sourcing plays an important role and determines the make or buy decisions. In case of external supply of goods and services, the contract, price, source and output quality are ensured through effective sourcing.

Pricing determines how much company will charge for its services and products. Pricing affects the service, behaviour of the buyer as well as chain performance.

VALUE STREAM MAPPING (VSM)

The understanding of the complete system operating in a synergistic manner is possible through the use of value stream mapping. The value stream mapping provides the snapshot of the processes in the manufacturing chain to identify wastes and defects for subsequent removal and process improvement.

Lean Manufacturing utilizes proper tools to make work flow as smooth as possible. Value stream management is a process of planning and linking Lean Manufacturing through systematic data gathering and analysis with production process to achieve the final product. The value stream of the manufacturing firm is identified which highlights the interlinked processes and operations generating advantage and value to the company. The suppliers, inventory, process, takt time and cycle time are mapped and improved through value stream mapping (Lasa et al. 2008).

Value Stream Mapping (VSM) is a systematic approach for production engineers on how and when to employ improvements that help to meet the customer demands (Zahoor et al. 2018). The Lean Management principles implemented from a VSM point of view are presented in Figure 2. The VSM is a traditional and complementary tool for Lean Manufacturing. It has been modified and used in other scenarios and modern manufacturing (Lugert, Batz & Winkler 2018).

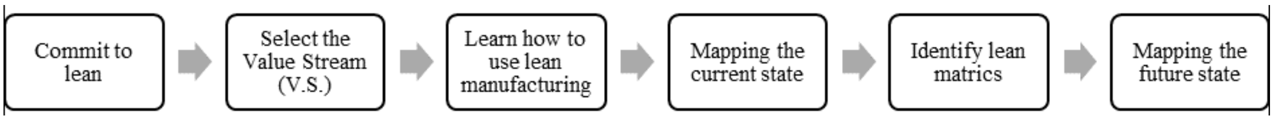

FIGURE 3. Research Methodology

METHODOLOGY

The study was conducted on a manufacturing unit of SME in Pakistan. The case organization was committed to the understanding and implementation of lean manufacturing principles. Preliminary background investigation was carried out in terms of business plan, company vision and mission, resources, product, market segment and human resource available. The secondary data was accessed to understand the case company as well as to understand the concepts of Lean Manufacturing and Value Stream Mapping. The manufacturing operations were analyzed in the case organization. This was done primarily through observations and interviews. The primary value stream identified was the engineering process chain observed as a subsystem of the SME supply chain. The current state of the manufacturing operations in terms of lead time, inventory, personnel, workstations and defects were monitored. The critical parameters and metrics which had to be improved were identified. An intervention or improved solution was presented based on Lean Manufacturing and evaluated for improvement. The flow chart of the current research methodology is presented in Figure 3.

The main objective of this study was to present the implementation of the principles of value stream mapping and Lean Manufacturing in the case of a ceiling fan winding machine manufacturer. Moreover, the intention was to explore the possibilities of lessening product waste, identify the non-value-added activities and compress the lead time of the product through the implementation of Value Stream Mapping. The study is conducted to implement appropriate changes in the industry to improve production and identify, analyse and propose solutions to reduce waste (Chen, Li & Shady 2010; Rahani & Al-Ashraf 2012).

The manufacturing enterprise selected for the study of applying Lean Manufacturing through Value Stream Mapping is located in the central area of Punjab, province of Pakistan employing more than 50 workers. The enterprise is manufacturing ceiling fans winding machine for local fan manufacturers and repair workshops. The ceiling fan winding machines are exhibited in Figure 4. The case organization distributes the product across four major cities of Pakistan other than the location of Manufacturing Unit. The aim of the company is to provide good quality ceiling fans winding machines at reasonable cost to customers. This company was founded in 2019 and is well reputed, growing, industrious and serving customers as per their requirement. It works on the model of single shift of 8 hours on daily basis.

The demand of the company's product is increasing due to prolonged summer season as well as growth in the construction industry. The size of the winding machine is small and affordable for fan manufacturers and repair workshops. Some components like wires, connectors and motors etc. are outsourced. The body of the machine is manufactured through various manufacturing processes like metal sheet cutting, profiling, drilling and welding.

The organization is a new entrant in the market. The establishment of recent operations and small company size puts focus on improving the processes, waste reduction and building knowledge for taking effective decisions. These points were attained by improving operations while increasing revenue earned by the use of VSM.

DATA COLLECTION

In this study, both qualitative and quantitative data were collected. The data was collected based upon the communication with the management of the company, interviews with the suppliers and workers, studying the internal documentation and conducting field observations.

Individual interviews were conducted with the Business Owner, General Manager and Workshop Engineer. These three individuals elaborated and presented a picture of the supply chain, manufacturing inputs, processes and outputs through a semi structured interview pattern.

The interviews were helpful to collect valid and qualitative data to the research questions and objectives. Observation study was also carried out to understand the production process. The workers operating in an 8-hour shift across 7 manufacturing stations performing various tasks were observed. Observations were conducted in the natural field setting. The researchers visited the mechanical workshop of the case organization several times. Data on workshop layout and operations were collected. The observation study for calculating the cycle time at each production station was conducted.

(a)

(b)

FIGURE 4. Ceiling Fan Winding Machine

Secondary data in the forms of company record was used in complement to the primary data. This data consisted of graphs, check sheets, drawings and other documents. The documentation contained the production procedure, the cycle times and lead times of the parts flowing through mechanical workshop machines (Kumar 2019).

RESULTS AND DISCUSSION

SUPPLY CHAIN ANALYSIS

Supply Chain is a complete integration of all entities in the production starting from the procurement of raw material till the sales and after sales services. All entities are engaged in business-to-business transactions with the consumer making the final payment to the chain which flows upwards. The supply chain of industries comprise of upstream suppliers, the focal firm and downstream customers. The global supply chains are evolving into supply webs with enhanced connectivity and features (Bugvi et al. 2021). Figure 5 presents a complete picture of the supply chain of the fan winding machine manufacturer. The upstream section includes raw material provider of cast iron and aluminium along with suppliers of electronic parts, chips, sensors and small items. Various outsourcing companies, transporters, distributors and market personnel are involved in the supply chain created through the sale of the fan winding machine. This supply chain of the SME plays its part in the generation of economic activity in the region.

MANUFACTURING OPERATIONS

Initial analysis was done to identify raw materials required and subsequent components which can be produced through casting and machining. The materials required are silver, iron, steel and aluminum. The study was conducted to identify the machining facilities and operations. The production was carried out in batches with process type layout. Process layout implies that similar machines were placed together to perform an operation simultaneously on job.

Lean Manufacturing of the winding machine using conventional operations (sand casting, molding and machining) and components assembly was observed in this case study as presented in Figure 7. Raw material was delivered at the manufacturing and production site. In the manufacturing phase, components such as keys, dyes and pulleys were molded through sand casting. Lathe machine was used to machine these parts into required sizes as per requirement. During the manufacturing process of small components, casing of winding machine was made from rolls of iron sheets. The sharp edges of these sheets were trimmed and pressed to form the casing structure. The casing structure construction also involved the drilling and welding operations. The next phase is to transfer these components to the production line where they were assembled together into the final product. Table 1 shows the time taken during each phase and the operations that were performed using relevant machines.

The continuous flow involving raw material, machining processes and final product across the factory is structured and presented in Figure 6.

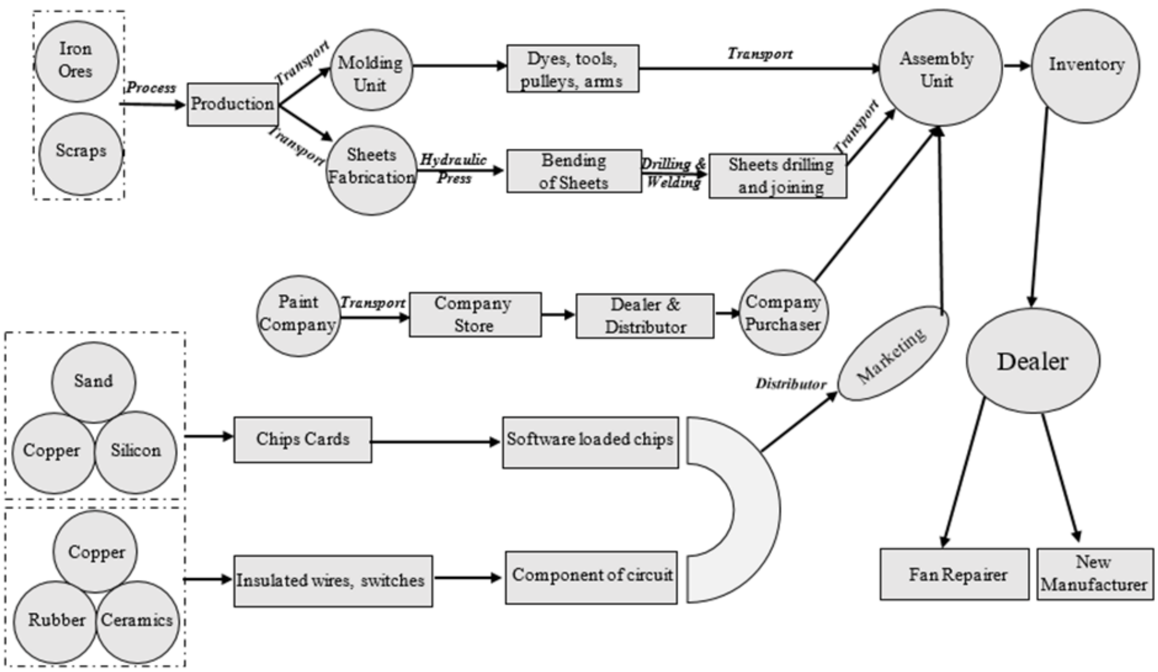

FIGURE 5. Supply Chain of Case Organization

VALUE STREAM MAPPING

CURRENT STATE

Current state mapping (CSM) describes the operating conditions occurring in production process at the present time. The Map (Figure 8) presents a complete picture of the production processes, machines used, manpower, cycle time, inventory units and lead time. This current value stream mapping shows the process in which three monthly order of materials are received from the vendor including iron sheets and paint. This material is then transferred to the metal sheet molding and cutting area.

After converting the raw material into required sheets, bends were produced to convert it into desired shape through pressing machine. Holes were drilled for fitting. Welding of different parts of sub-assemblies was performed in the welding shop. The components were finally sent to the paint shop. After the inspection of winding machine components, the items fulfilling the quality requirements were sent to the assembly line. The time taken in each operation and the material handling time from raw material delivery till the end of assembly of final product is shown in the Figure 8. The time taken for 1-shift of workers of 8hrs, took a processing time of 14,090 seconds and the production lead time of 48.3 days by the current process map is shown in the Figure 8.

TABLE 1. Machining Operations, Materials and Components

Machine	Materials	Components	Operations	Time
Molding	Sand, Binder, Alloys.	Keys, dyes, pulleys, bearing seats and foundations	Sand Casting, Molding	
Lathe	Aluminum, Iron Bars	Machine Parts, Boots, Bottles, Armature.	Grooving, Cutting, Turning, Sanding	
Metal Sheet Cutting Machine	Iron Sheets	Metal Sheets to make body of Machine	Metal Sheet Cutting	8-9 Minutes
Press Machine	Iron Sheets	Sheet Metal Body	Pressing and Shaping	8 Minutes
Drilling Machine	Iron Sheets and Molded components	Metal Body of Machine	Drilling	15-20 Minutes
Welding Machine	Iron Sheets and components	Complete Frame and parts are joined	Welding	20-25 Minutes
Paint Machine	Body and Frame of Machine	Spray Paint and Drying	Spray Paint	180 Minutes
Assembly	Body, Frame, Motor, Relays, Connectors, Switches, Parts	Assembly Production	Manual Assembly	50-60 Minutes

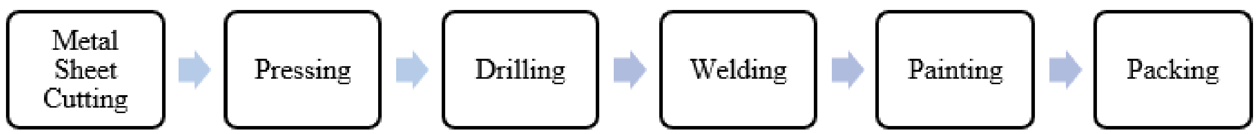

FIGURE 6. Ceiling Fan Winding Machine Manufacturing Process

ANALYSIS OF THE VALUE STREAM

The analysis of the Value Stream may be grouped into four categories namely raw material supply, inventory, production and distribution.

RAW MATERIAL SUPPLY

The raw materials come from different suppliers as per customer requirement. Ideally, these are generated after production department specifies the requirements, originating from master schedule planning. The responsibility for ensuring raw materials availability lies with stores and procurement department. The raw material supply is a 3-month cyclic process with inventory being stored at the warehouse which is located 6 km away from the factory.

STORES AND INVENTORY

At the time of this study, the plant had no standard inventory control system. Raw materials stocks were monitored manually. The manufacturing buffers are arranged in a linear model. The downstream side has decreasing inventory buffer. The further the product is upstream in the supply chain, the greater is the buffer requirement. It is ranked as the second major waste. Inventory losses were caused by defects and poor planning in transportation, motion and unbalanced process flow. Line balancing techniques were used to develop the Future State Map (FSM). In this process, the implementation of first-in-first-out (FIFO) between product start and completion ensures so that no unnecessary product units would be kept waiting at work stations.

(a)

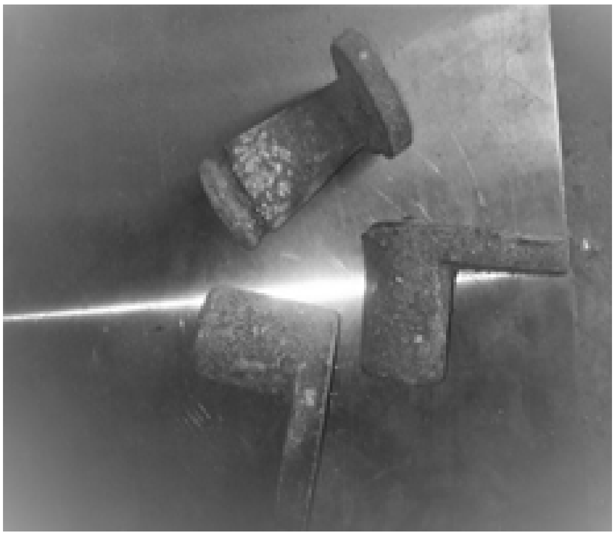

FIGURE 7. Ceiling Fan Winding Machine Components (a) Cast Iron (b) Steel

PRODUCTION

The timeline shows that the process consumes about 48 days from transferring raw materials to manufacturing 100 ceiling fan winding machines. The current state map helped visualize the whole process and indicated areas where defects were emanating. Many processes in workshop are being carried out manually increasing the chances of defects. Some defects are corrected which requires time and effort. Defects could be present in raw material, production or may be due to machine maintenance issues.

MOTION

Wastage in motion is due to the manual process of loading and would be less in case of semi-automated process. The on-line storage needs to be considered for redesigning the production line. This would facilitate the linking of production, stores, sales and marketing together to avoid unnecessary motion. The development of an economic batch quantity to be transferred optimizes the motion required for ceiling fan winding machine.

AVERAGE WEIGHT OF WASTES IN CASE ORGANIZATION

The seven wastes were weighted on the basis of 10 points per waste scale. The minimum value was taken as zero with maximum occurrence at ten. The average value was 5 and the scale indicates small, moderate and high forms of wastage occurring in the production process as per the perception of management and workers. The total score on the waste index was 32 points out of 70 with transportation losses and piece defects scoring significantly higher as compared to other waste categories.

TABLE 2. Average Weights of Wastes

Sr. No.	Wastes	Avg. Weights
1.	Overproduction	4.5
2.	Waiting	3.1
3.	Transportation	7.4
4.	Inappropriate Processing	4.5
5.	Unnecessary inventory	3.1
6.	Unnecessary movements	4.2
7.	Defects	7.8
	Total	32/70

FUTURE STATE ANALYSIS

The Future State Map was developed and it outlines the envisaged improvements by using the VSM tool. The waste and associated problems of current state map were carried forward and subsequent solutions proposed in the future state map (Figure 9). In this map, the two processes namely drilling and welding which were separated in the current state map, were combined. It was observed that upon combining these two processes, a reduction of 19% in the processing time from 14,090 seconds to 11,300 seconds was achieved. Furthermore, the current value stream mapping lead time was reduced from 48.3 days to 38.3 days. representing almost 21% improvement. The improved results of Future State Map are shown in Figure 9.

The mapping of the current manufacturing status and production time taken gives an insight for product requirements and associated areas of improvement. The areas of improvements are in terms of manpower, workstations, operations, motion, wastes, defects and inventory. The proposed changes given in the future state map involves significant improvements in the manufacturing chain. This was done by combining two processes (drilling and welding) together. This modification was based on making the process cost effective by reducing the overall time taken without any additional cost of workforce, material or the equipment improving the overall process.

SOLUTIONS FOR REDUCING WASTAGE

Suppliers: The suppliers of case organization should supply orders on time. In house and overall inventory can be reduced by utilizing Just in Time (JIT) technique. If the suppliers do not deliver on time, the case organization may face financial problems and shut down. The trust of customer on company is also affected. The case organization should take raw material from direct supplier so that the cost of raw material is reduced and long-time agreements can also be made. This will limit the need to store raw material in bulk quantity. The financial savings occur due to little fluctuation in buying prices and loss of material due to obsolescence. The first solution is to ensure JIT delivery from supplier through better transportation and orders as per need.

There is a need to change the layout of case organization to reduce cycle time. The waste of warehouse and production can also be reduced if the organization decides to change the production method from 'make-to-stock' to 'make-to-order'. This will help to reduce extra stock of raw material and extra production. The waiting time also reduces due to efficient and suitable material handling.

Transportation: The transportation facilities of company are adequate but improvements can be made in scheduling and operations. The suggestion is to decrease the waste of transportation by making the transport department responsible for on time delivery and supply. The case organization can make a small storage place on site for final products. The option to store inventory directly into on line machine buffers should be explored. The direct provision of outsourced components to machining stations following JIT principles in a cyclic manner through efficient transportation is desired.

Unnecessary Inventory: Unnecessary inventory of raw material should be avoided. In order to decrease the unnecessary three monthly bulk supply of raw material, close relationships with the suppliers should be developed. The safety stock could also be reduced when the production processes are optimized.

The unnecessary inventory of finished products is also reduced when the pull policy is implemented. The company should purchase sheets of required dimension to reduce waste of material. The scrap should be used for making small parts such as rings along with reuse of molten residue in moulding machine. It is recommended to avoid preparing large amounts of components to save money, time and material. Furthermore, there is no need to store unnecessary inventory in machine shops. Only needed parts are worked upon correctly and quickly.

Unnecessary Movement: Unnecessary movement should be reduced as this is a major cause of time and resource wastage in industry. The case organization stores raw material in warehouse and then take it to working area. The loading and unloading work are carried out twice, first from supplier in store and then in the machine shop. Changes in layout to reduce movement of material from warehouse and between working stations should be implemented and the process should work continuously without fluctuations.

Defects: Many processes in workshop are performed manually so defect rate is high. Defects may be present in initial raw material, production machining, and due to lack of maintenance, mishandling of material, improper painting, picking and packing of products etc. The minor and major defects all contribute to overall loss in the system. This wastage is removed by making changes in process layout and applying the Just in Time or Lean Manufacturing principles.

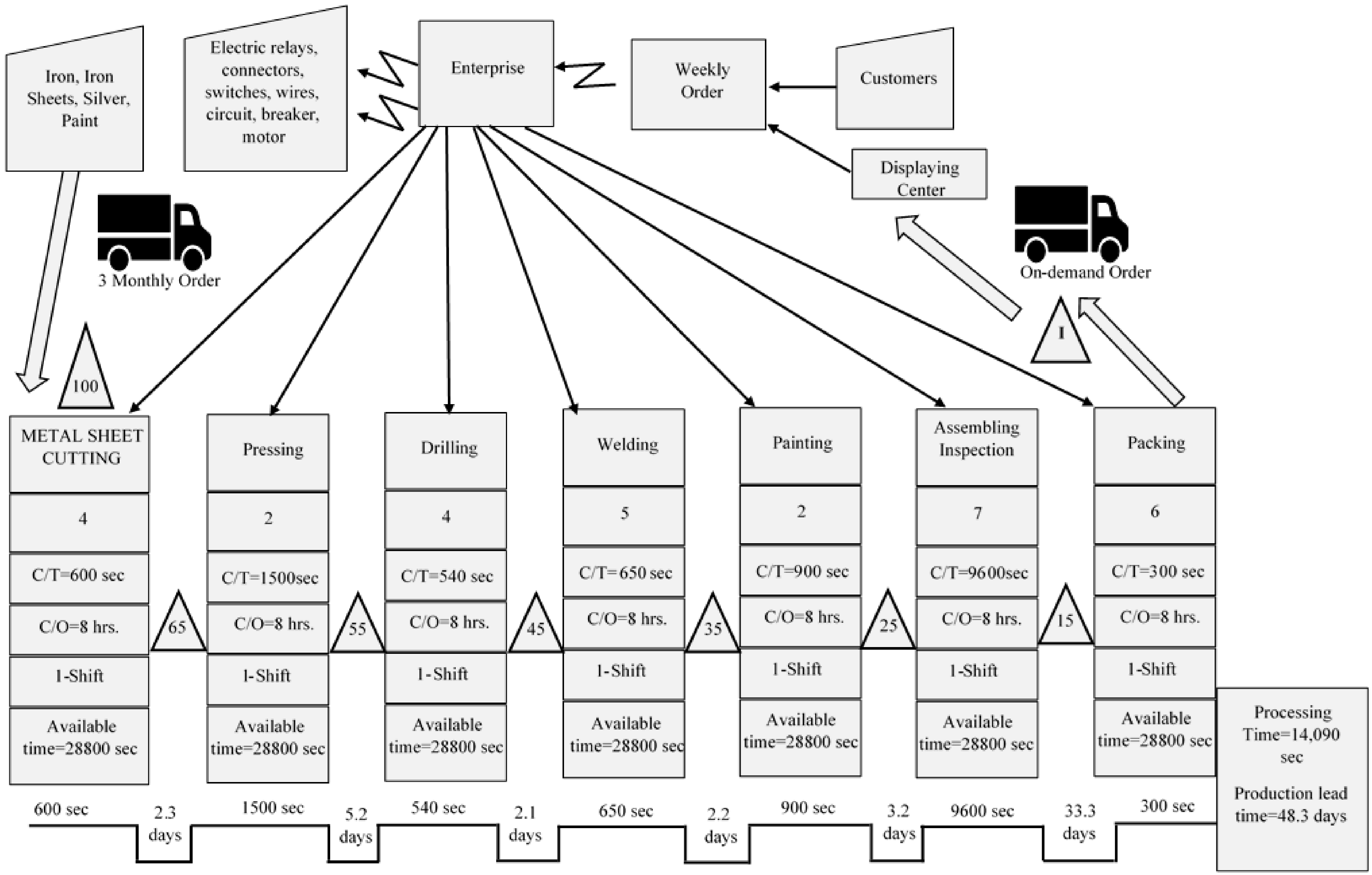

FIGURE 8. Value Stream Mapping of Current State

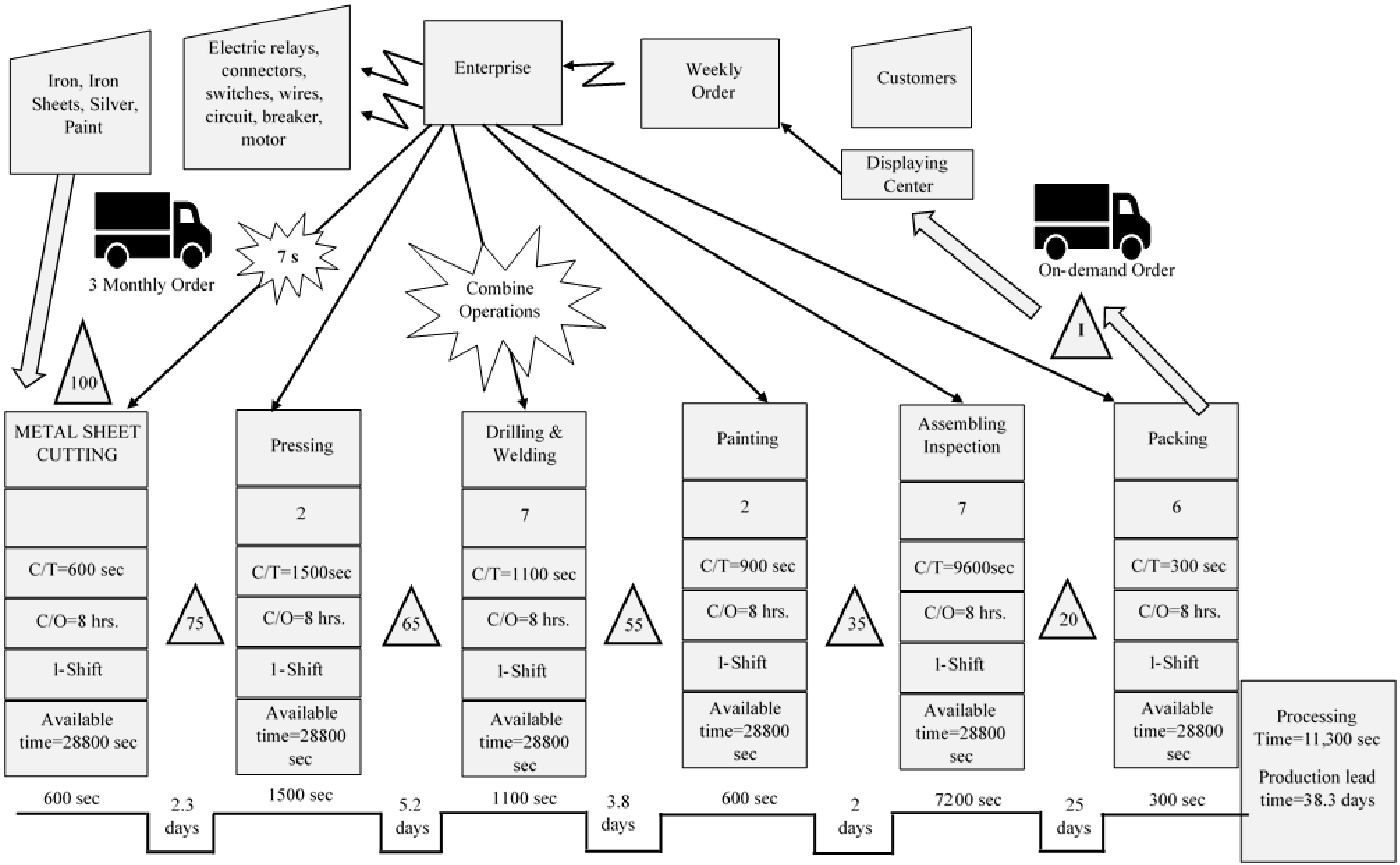

FIGURE 9. Value Stream Mapping of Future State of Case Organization

CONCLUSIONS

The study of the company resulted in the current state map which points out important wastages: waiting, transportation, unnecessary inventory, unnecessary motion, unnecessary finish products and defects. Two most common reasons were found for the wastages. The first one was the requirement of compulsory minimal quantity of raw material to be ordered from the suppliers, contributing to the wastes of waiting, transportation, unnecessary motion and inventory. The second reason was the improper workshop layout that contributed to all five identified wastes, leading to defects.

The study maps the organization systematically through VSM. The intervention suggested is layout modification by reducing 7 stations to 6 stations and streamlining the operations. The layout modification results in lower defects, controlling overproduction, managing inventory buffers from a linear approach to an optimized level, reduction in processing time of each unit by around 19 % and the production lead time of 100 units by around 21%. The study through VSM proposes improvement through enforcing pull system, improving supplier relations, modifying layout and production processes, JIT delivery of materials and parts, scheduling transport resources efficiently and reducing inventory buffers.

Reduction of the identified wastes leads to managerial consequences. First of all, relations with suppliers, customers and transporters should be strong and long lasting. It is important to note that all the supply and production chain entities would benefit from these findings in terms of waste reduction for inventory, motion, and waiting.

In this study, transportation schedule and cost might require additional analysis. Secondly, the workshop design is currently represented by the process layout divided into operations. It is suggested to form the cellular or product layout as a strategy to improve performance. This would result in reduction of transportation within the company, unnecessary motion, defects and excess inventory.

Next, the decoupling point is currently located in warehouse which could be moved upstream. Production has to be based rather more on customer orders than on forecasting, mainly for inventory reasons and for speeding up the order fulfilment. The main advantages of the proposed future state map are faster order fulfilment, optimized process, increased visibility and control of raw material requirements and reduced costs of other processes. The future state map is presented to be a useful starting point for improving efficiency of product flow.

This case study methodology and findings are believed to be useful for other companies having similar profile and problems in their production process value stream. The value stream mapping method was applied to prepare a value stream including the suppliers and customers in order to identify the wastes. It was concluded that the value stream mapping method could be used effectively for performance improvement, along with additional mapping and analytical tools, supplying a more detailed picture of the manufacturing value stream.

DECLARATION OF COMPETING INTEREST

None

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