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Designing a Future Value Stream Mapping to Reduce Lead Time -A Manufacturing Real Case Study

Ashish Thakur[1], Eshetie Kassegn[2]

School of Mechanical and Industrial Engineering, Mekelle University, Mekelle, Ethiopia
keshetie61@yahoo.com, thakurashish1@gmail.com

Abstract

Companies in the manufacturing industry today are faced with increasing challenges with respect to cost effectiveness, lead time and quality of the production system. Mesfin Industrial Engineering and other Ethiopian manufacturers struggle with improving productivity, producing the right products or services at the right place and meeting on-time delivery. The main objective of this study is to design an efficient Value Stream Mapping (VSM) to improve the productivity in Small Medium Enterprise (SME) by eliminating non-value added activities. Dealing with these contradictory goals, an important task is the selection of suitable solutions with new proposed model for the integration of identification processes within the process chain, which are necessary to ensure the required production quality. For this, supportive and easily applicable planning techniques are required to analyze and design the configuration of an individual respective process chain. MIE has implemented some improvement tools and techniques such as quality management system (QMS), kaizen, quality circle, and 5S; however, the required change didn't come. So, value stream mapping technique is found suitable to bring the required improvements by identifying major wastes and reducing those wastes encountered the company in manufacturing of dry cargo trailer. A future value stream map is then established to highlight the improved area and applied lean tools. As a conclusion, this paper presents that the designed Future Value Stream Map (FVSM) helps to effectively identify wasteful activities and production processes. The implementation of the developed approach is exemplarily shown for a complex value chain of a manufacturer in the automotive industry, Ethiopia.

Keywords: Value Stream Mapping, Lean Manufacturing, Waste, Lead Time

1. Introduction

The main objective of this study is to design an efficient Value Stream Mapping (VSM) to improve the productivity in Small Medium Enterprise (SME) by eliminating non-value added activities. Value Stream Mapping (VSM) techniques of lean manufacturing system used for conducting the research. It is a Lean process mapping tool for understanding the sequence of activities used to produce a product. Lean Production System (LPS) is the systematic approach of identifying and eliminating all wastages through continuous improvement to pursuit customer satisfaction [1]. LPS was guided by five principles starting by 1-specifying value, 2-identifying the value stream, 3-making the value flow, 4-configuring of pull system by customer, and 5-pursuing towards perfection [2, 3]. LPS consists of a set of powerful "tools" that assisted in the identification and steady elimination of waste (Muda) such as VSM,5S,SMED and standardized work[4].The first step to implement lean manufacturing tool in any organization is to apply Value Stream Mapping (VSM).The value stream is analyzed and mapped in order to reduce the waste in processes, enable flow, and move the process towards the ideal of rapid response to customer pull [5, 6, 7]is highly applicable for manufacturing oriented industries. According to [8], the research at the Lean Enterprise Research Centre (LERC) in the United Kingdom, and the discussion made by [9] on the title "Fundamental Productivity Improvement Tools and techniques for SME indicates that for a typical manufacturing and production operations company, the ratio of activities could be broken down namely as value-added activity, non value-added activity and necessary non value-added activity with 5%, 60% and 35% respectively. This implies that up to 60% of the activities at a typical manufacturing company could potentially be eliminated. Therefore, conducting the research with related to VSM is not only an important one but it is also a mandatory to eliminate or minimize that large amount of non-value adding activities with the case company. Value Stream Mapping (VSM) is a state of the art tool which is very often used for this by professionals. It, however, is not capable of addressing the issue of a suitable integration of testing processes within the process chain. Yet, this provides valuable potential to facilitate the identification of effective testing equipment, testing strategies and quality control loops. Therefore, in this article an innovative model approach called Future Value Stream Mapping (FVSM) is presented. Inefficient manufacturing processes are the result of doing unnecessary activities which promotes wastes and increases delivery time. Value stream mapping is a technique and tool of identifying both value-added and non-value added activities via mapping the process of material and information flows from input to output, and focuses on increasing time spent for value added activities to the product. So, in pursuit of elimination or minimization of manufacturing wastes, the future state value stream map has been developed from the current state value stream map. The future state value stream map was developed by taking considerations on minimization of work-in-progress inventories, reduction of changeover times of each process, minimization of distances travelled while manufacturing the product, avoiding unnecessary activities, and redesigning cells layout which facilitate the flow of the product. The VSM is a pictorial representation of the activities required to produce a product or service from raw material to the customer. A VSM differs from other mapping processes such as process mapping and flow charts [12]:

- Includes the amount of inventory that exists between activities
- Includes the information flows for the product as it travels from end to end
- Provides a timeline showing the processing time and total lead time

2. Literature Review of Value Stream Mapping

Starting in the 1900's Henry Ford "married consistently interchangeable parts with standard work and moved conveyance to create what he called flow production." After WWI, the Toyota Production System (TPS) introduced lean manufacturing concepts into the manufacturing industry [11]. [10] Defined lean as a system that consumes less of all inputs to provide the same output as created by mass production system but increase varieties of products for customers. According to the paper "A road map to lean manufacturing success [12]", if any company is following the strategy of mass production system, the company will purchase more expensive capital equipments. By applying lean in a right way to a company, it is possible to improve the quality of the products and services, reduce waste (including time waste) and costs, enhance operations effectiveness, and maximize profit as well as market share; ultimately, it is important for the improvement of the company from the economic perspective. Lean can be viewed as having both a philosophical and processual element. The lean philosophy is characterized by end user focus and total system efficiency, employee involvement and respect for people, continuous improvement, and waste elimination [13]. [14] Studied that the implementation and practicing of lean manufacturing is very important for responding to competitive challenges through applying various implementation tools of lean manufacturing system. According to the conclusion of [15], lean has been proven to be an effective management philosophy for improving businesses in a competitive market by eliminating waste and improving operations. Thus, it is the potential solution over other improvement methodologies and approaches for businesses trying to focus on waste elimination and producing products that meet customer expectations in terms of quality and on time delivery. The production cost will be reduced when the waste is reduced or eliminated through applying basic tools and techniques of lean manufacturing.

3. Objective and significance of the study

The primary objective of this research was to reduce the lead time (the total elapsed time from receiving order to delivering the output) by at least 50% through applying the principles of lean tools and techniques, especially the value stream mapping one. The general objective of the study is to develop value stream mapping for the process of dry cargo trailer production line at Mesfin Industrial Engineering (MIE) plc. While the specific objectives of the study ware:

- ✓ To analyze the value stream of dry cargo trailer manufacturing process;
- ✓ To create the current state value stream map of the manufacturing process;
- ✓ To analyze the root causes of problems associated with wastes, time and cost, and apply effective countermeasures;
- ✓ To eliminate or minimize the non-value adding activities in the process;
- ✓ To propose the future state value stream map of the process which can increase the value added activities and reduce non-value added activities, lead time and wastes;

As already discussed above, the manufacturing sector in Ethiopia is growing tremendously from time to time. Even though the sector is growing faster, the products produced by manufacturing industries are not capable of computing with other nations' products in the world in terms of quality and price. This is because of high wastage of resources and luck of well understanding about modern management philosophies of performance and efficiency improvements. Therefore, the research is very important in addressing solutions how to identify and analyze wastes in manufacturing processes, and give up a clear direction how to improve the overall process.

4. Methodology

4.1 Material Preparation

A MIE case study as SME is considered producing cargo trailer. Work In progress (WIP) of trailer was transported to different departments for Testing and packaging. Before the packaging, the trailer will be assembled into the smart, casing and proceed to the FCT. The packed smart tag units will then be shipped to the customer.

Material preparation is done at preparation shop (shop floor). All components of the product (except some accessories like axle, trolley etc.) are prepared at this shop by using different machineries and equipments. Activities to be done at each machine and equipment are specified. The following are the main activities done at material preparation process. For detailed information about the components manufactured at the following processes, see on Table 1.

a. Shearing (cutting and chamfering) with required dimensions using two shearing machineries;
b. Bending using two bending machineries;

c. Cutting materials using power hack saw;
d. Cutting materials with different angles and lengths by band saw machine for gear supports;
e. Cutting long materials with required shapes using pantograph machine;
f. Rolling materials with required shapes and sizes using roller machine, but in case of dry cargo trailer this operation is not required because no part is rolled;
g. Rectification and Grinding;
h. Manual flame cutting; and
i. Notching for chamfering.

The fabrication process is done at its dedicated places (fabrication shop two and auxiliary shop). Board preparation, stand fabrication and grill fabrication are done at auxiliary shop. The remaining components are fabricated at shop two. The main activities were done at fabrication

Table 1: Main components manufactured at material preparation shop

Machines and activities	**Main components manufactured are:**
Shearing	Side plate for front boards; Chequer plate longs; External cross members at front, rear; Internal cross members; Cross members (long, medium and short); Draw bar side frame; Cover plates; Ring fixing I-beam; Draw bar cover plates; Plates at front, rear; Side, front and rear beams; Side omegas; Central omegas short, long; Omega for front board; Stands; Front, side and rear boards; Reserve fuel tanker plates; Mechanical hand brakes
Bending	External cross members at front, rear; Front, side and rear beams; Internal cross members; Side omegas; Central omegas short, long; Draw bar frame; Cross members (long, medium and short); Plate at rear; Side, front, rear boards (1st and 2nd steps); Reserve fuel tanker plates; Side plate for front and rear boards; Front, side and rear stands; Omega for front board
Power hack saw	U-channel for air cylinder support; U-channels; U-channel support fuel tanker; Wheel clamp rod; Axel support tube; Twist lock support (big and small); RHS
Band saw	Platform and trolley beams; U-channels
Pantograph	Web plate; Connecting plate; Lower and upper plates
Rectifying and grinding	Web plate; Connecting plate; Lowe and upper plates
Manual flame cutting	Draw bar cover plate
Notching	Movable joints; Clearance light; Rolled plate; Triangular hook r/f; Break house support (plate form); Stand covers; Fixing plate for opening stand; Angle iron for opening stand; Plate for tool box locking; Bumper cover

Processes lead majorities of the manufacturing processes of the product to be finalized except painting, finishing and quality checking. Finishing is the last process in production of the product which encompasses assembling and welding of accessories on the product, decorating, inspecting and testing the product; then draining out the product from the process to deliver it to the customer. The times have been assigned for each activity allocated at this process by production department, but the assigned times can be reduced to a value through avoiding unnecessary activities and increase performance of employees. The main activities and the corresponding times assigned for each activity are given on Table 2.

Table 2: Main activities at finishing station (Source: Finishing Division)

Activity	Manpower		Target time		Number of products per day
	Skilled	Semi-skilled	(Hour/unit)	Days	
Installing breaking system	1	1	2:00	1	3
Installing electric system	1	1	0:30	1	15
Installing accessories	1	3	1:00	1	7
Checking quality	1	0	0:30	1	15

Accessories installed at this process are reserve fuel tank, mud guard, reflector, logo, and mechanical hand break. Air tank (cylinder) is connected to the breaking system, and it is a breaking system. Junction box (light box) is one of electric system. Both breaking and electric systems are installed simultaneously before assembling and welding of accessories. Then, installation of accessories is begun after completion of breaking and electric systems installations (Figure 1). After finalizing all these tasks, the product is subjected to quality checking after 3 hrs of accessories installation.

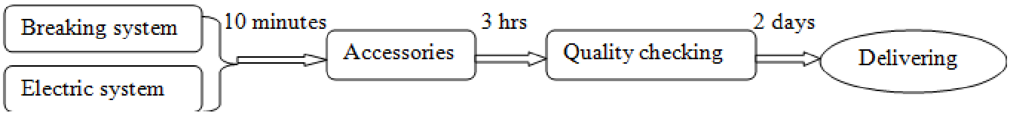

Fig.1.Sequence of activities and WIP times at finishing process

To exist in competitive market, companies are forced to exert much of their effort on creating lean environment to be lean enterprise. Some manufacturing companies like MIE PlC have started implementing lean production system with some extent following the principle of kaizen (continuous improvement) and 5S.Toyota has concentrated on improving their own efficiency through cutting of costs, improving quality and reduction of lead time [16]. As per the results shown by [16] and theory as well as philosophy of some organizations [17], continuous and successful implementation of future state map is developed and practiced based on various factors from structural, strategic and cultural perspectives. Data were gathered from the case company to identify wastes encountered it with their root causes. Then, it was used to create the map of the existing value stream, and used again as the road map for the design of the future state map. Both qualitative and quantitative methods were used in conducting the research because the issues inbounded in this research would be related to quantitative as well as qualitative aspects. Numerical or quantitative related values have been collected and analyzed. Qualitative related data have also been collected and analyzed. The survey strategy was usually associated with the deductive approach. Using this method allowed the collection of a large amount of data, which afterwards was analyzed.

5.0 Case study: The Mesfin Industrial Engineering

The research was conducted at Mesfin Industrial Engineering (MIE) PLC which builds bodies of eight automotive products. The company is operating under "make to order" strategy of manufacturing, which means it does not keep a large inventory of finished parts and only creates a certain number of parts depending on customer demand. Value stream mapping has not been used by MIE as a strategic tool for operational improvements. The objective of this research was to reduce the lead time (the total elapsed time from receiving order to delivering the output) by at least 50% through applying the principles of lean tools and techniques, especially the value stream mapping one. To achieve this objective, the current state of the production process was first documented and analyzed. Then, based on the results obtained from analyzing of the current state of the production process, the future state was designed to improve the whole production process through reducing the lead time and wastes using some improvement techniques and tools. In manufacturing of dry cargo trailer product under Mesfin Industrial Engineering (MIE), there are many activities done which couldn't add value to the process and product, and facing problems of material flow (in which material is flowing from one process to the next process in batches) as well as workflow (activities which could be done in the same station are done in different stations); and the information flow is also difficult in which it couldn't allow every concerned body in each stations to be aware of what has been done so far and is going to be done in the production processes. The information flows from the production department to each station in the production process, but no communication among stations. As a result of these, the effects of long lead time for delivering the product to customers (more than three months), high cost of production (due to internal failure costs which is more than 40,000 birr per year) and high wastage of resources (800 meters distance travel in manufacturing the product) are specific problems which challenge the company. These problems could be solved by applying lean manufacturing tools and techniques, specifically value stream mapping (VSM). It is well known that leading companies could be competitive and profitable through applying appropriate processes and lean manufacturing principles. Lean manufacturing, particularly VSM improves the efficiency of the processes from the input up to the output by minimizing if possible by eliminating non-value adding processes. In doing this, mapping the current value stream is the first step. Then, it is possible to identify wastes and unnecessary steps in the processes, and minimize or eliminate them. Finally, redesigning the predicted value stream map is followed, and then the new value stream map is implemented. Therefore, this research is intended to address a solution of identifying and eliminating or minimizing of non-value adding activities, and minimizing lead time as well as wastes encountered the company. Thus, it is expected to develop a value stream mapping for the entire processes of dry cargo trailer production line through identifying and eliminating or minimizing the non-value adding processes that results in reducing lead time. Thus, this study focuses on identifying and reduction of non-value adding activities by redesigning the material and information flows, and improving the overall performance of manufacturing the dry cargo trailer using value stream mapping tool and technique. As a result, wastes, production cost and delivery time are reduced to significant values.

5.1Data Collection

5.1.1 Primary Data Collection

Collections were done in five segments tried to understand, analyze and solve the problems

a. Visual observation: This method has been used to visualize the overall performance of the company's activities, and to come up with some concrete ideas. It also gave general understanding of what will be done to solve the problems.
b. Questionnaire: It was used for this study to dig out the feeling of employees of the company about the study to be conducted. It was also used to gather the relevant data about the current status of the process and the company's performance in terms of improvements.
c. Interview: It was used to collect data from the company related to the study from the managers' side/perspective. Even if this method was challenging to collect data, it was very important to obtain more relevant primary data about the overall activities and strategies of the company.
d. Focused group discussion: This method was the one used to gather raw data related to the study based on the facts and suggestions by discussing with experts.
e. Time Study: Time study was conducted to determine the cycle time per dry cargo trailer at each station, the lead time from receiving order to delivering the output to the customers, the down time due to failure and maintenance of machines, the time taken to move the dry cargo trailer under processes from one station to the next one, the time taken to transfer materials from materials stores to the production lines and determining the time lost due to materials waiting. The current state value stream map (CVSM) was drawn in which the future state value stream map (FVSM) was also drawn on the basis of the CVSM with certain improvements of different aspects.

5.1.2 Secondary Data Collection

a. Company background: Secondary data were accessed using company background. It was used to know the company from its initial to the current up-to-date status. This was applicable to understand the level of improvements of the process for manufacturing of the product from the establishment time to the current time.
b. Documents from the company: Relevant data were directly collected from the documents of the company such as reports, manuals and standards, and these data were used for the study.
c. Related books and papers: Facts related to the study have been collected through accessing books related to the research. Websites were also used to access papers or journals related to the study. This was very important to understand and apply the scientific facts and implications of the study.

5.3 Data Analysis

After relevant data have been collected, data analysis was conducted using different approaches.

a. Value stream mapping tools: There are eight basic value stream tools used to analyze and map the value stream of the process. These tools are the following: process activity mapping (PAM), supply chain response matrix (SCRM), production variety funnel (PVF), quality filter mapping (QFM), demand amplification mapping (DAM), decision point analysis (DPA), physical structure (PS) and, value adding time profile (VATP) [7].

Table 3: The Eight VSM tools and their purposes [7]

S/N	VSM Tools	Purpose
1	Process Activity Mapping (PAM)	It aids in developing solutions to reduce waste
2	Supply Chain Response Matrix (SCRM)	It aids in identifying the activities constraining the process so that these activities can be targeted for improvement
3	Production Variety Funnel (PRV)	It is similar to VATP analysis and helps one understand how products are produced
4	Quality Filter Mapping (QFM)	It aids in identifying where quality problems occur
5	Demand Amplification Mapping (DAM)	It aids in analyzing the increase in demand variability as one travels up the supply chain, otherwise known as the bullwhip effect
6	Decision Point Analysis (DPA)	It aids in identifying "the point in the supply chain where actual demand pull gives way to forecast-driven push"
7	Physical Structure (PS)	It aids in developing a high-level understanding of the supply chain
8	Value Adding Time Profile (VATP)	It is used for looking at time compression or mapping out where money is being wasted

Table 3 shows that the seven types of value stream mapping tools with respect to the seven types of wastes probably occur at the operation or process. Process activity mapping involves the following simple steps; the first is undertaking a preliminary analysis of the process, and following detailed recording of all the items required in each process; resulting develop map of the process in terms of variety of activity types as operation, transportation, inspection and storage[20]. Table 4 depicts key facts on stream mapping.

Table 4: The Seven Stream Mapping Tools [18, 19]

Wastes/ Structure	Mapping Tools						
	Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Physical Structure a) Volume b) Value
Overproduction	L	M		L	M	M	
Time waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Product defects	L			H			
Overall structure	L	L	M	L	H	M	H
Origin of tool	Industrial engineering	Time compression/ logistics	Operation management	New tool	Systems dynamics	Efficient consumer response/logistics	New tool
Note: H= High correlation and usefulness, M= Medium correlation and usefulness, L= Low correlation and usefulness							

There are five stages to this general approach.

1) The study of the flow of processes;
2) The identification of waste;
3) A consideration of whether the process can be rearranged in a more efficient sequence;
4) A consideration of a better flow pattern, involving different flow layout or transport routing; and
5) A consideration of whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed.

Softwares such as Microsoft Visio software, Statistical techniques and methods, Smart Draw 2012 and EVSM v5.39 were used to carry out study cause and defect diagram of major problems, identifying value adding and non-value adding activities, drawing current state value stream mapping and map of value stream of the dry cargo trailer respectively. A survey based research was conducted using samples from the population.

b. Microsoft Visio software: This software was used to map or draw the cause and effect diagram of major problems. It was also applied for putting column charts.

c. Statistical techniques and methods: It was used to analyse the value stream by identifying value adding and non-value adding activities. It was also used for analyzing the machines performance, additional cost, and all time related data.

d. Smart Draw 2012 software: It is trial version software, and was used to draw the current state value stream map. It contains all relevant icons or symbols of value stream mapping.

e. EVSM v5.39: This is a value stream mapping trial version software. It was used to map the value stream of dry cargo trailer. Using this software, the future state value stream map was drawn by considering certain improvements on current state value stream map. All icons of the map of value stream are found from this software.

6.0 Results Analysis and Discussion

Respondents were selected from different departments based on their professions, experiences, skills and sexes. The questionnaire was designed mainly for collecting information related to value streams, wastes, both processing and lead times, and number of operators in each process during manufacturing of dry cargo trailer.As the information obtained from the respondents, the company is facing the following problems; supply of raw materials of the product, delay in delivery time of the product to customers, skilled persons turnover, quality problems, raw materials wastage and problem of reusing waste, design problems, machines idleness and downtime, no proper production flow and operational time estimated, marketing problem, no enough suppliers, inventory and manpower management problems, supervision problem, and integration among departments problem. To solve the problems and bring improvements on processes and products, the following improvement tools such as Kaizen, Five S (5S), Quality management System (QMS), and Quality Circle are used by the company. Product design improvement, process simplification and employee evaluation are also used as an improvement ways, but are not well implemented on the way to improve the overall process (Refer Figures 4, 5 and 6). The integration between the flows of material and information is very important in improving the overall process of manufacturing the product. Half of the respondents are not well aware about the linkage between material and information flows. All the respondents were also agreed that the space utilization of the company is very poor. There is a wide area around the manufacturing processes which is not used properly. Currently, the manufacturing process is running with two shifts per a day, and the batch size is limited to 10 units per batch. Manufacturing of the product proceeds when order comes; otherwise, production will interrupt. Delivery time of raw materials and accessories is also another factor result in interruption of production since the time required to deliver raw materials

Table 5: Summary of data obtained from respondents

S/N A	**Seven Wastes and others**	**Number of Respondents said:**					
		High	**Medium**	**Low**		**Any other**	**Not responding**
1	Inventory	14	11	3		0	0
2	Waiting time	12	11	4		0	1
3	Over production	2	8	12		3	3
4	Transportation	10	10	6		0	2
5	Over processing	4	12	8		2	2
6	Motion	8	8	8		0	4
7	Defects	6	10	11		0	1
8	Rework parts	2	12	9		1	4
9	Scrap rate	4	13	7		2	2
10	Manpower utilization	9	13	4		2	0
11	Material utilization	7	16	3		2	0
12	Production cost	10	12	4		2	0
13	Maintenance	10	10	6		0	2
14	Customer satisfaction	14	12	1		1	0
15	Machines failure	4	16	7		0	1
16	Overtime requirement	7	8	9		1	3
17	Quality of the product	15	8	3		2	0
B	**Human Resources**	**Number of Respondents tick (√) on:**					
		1	**2**	**3**	**4**	**5**	**Not responding**
1	Team approach	2	0	8	9	3	5
2	Multi-functional workers	0	7	10	6	5	0
3	Training	2	8	6	6	5	1
4	Employee satisfaction	0	4	13	8	3	0

C	Lead Time	1	2	3	4	5	Not responding
1	Machines setup time	2	5	11	7	3	0
2	Material handling time	1	4	12	5	2	4
3	Processing time	2	3	7	11	3	2
4	Work-in-progress time	0	1	11	4	6	6
5	Changeover time	1	4	10	4	1	8

and accessories is inconvenient and unsustainable. The intension of the analysis part is to analyze and discuss the resources utilization, causes of major problems, and performance efficiencies of the processes in manufacturing of the dry cargo trailer after mapping the current state value stream; and to design a future state value stream map which enhances the performance of the processes in manufacturing of the product considered. The processes in manufacturing of the dry cargo trailer after mapping the current state value stream; and to design a future state value stream map which enhances the performance of the processes in manufacturing of the product considered. The data about the level of wastes and resource utilization were also collected. Thus, the data regard to waste indicates that all the eight types of wastes are existed. The resource utilization is not optimum as of the respondents. The data obtained from respondents are summarized above as shown on Table 5.

Problems analysis using Tools (Cause and Effect Diagram)

Main problems facing the company in manufacturing of the product have been analyzed using cause and effect diagram. This was done based on the information from respondents, self-observation and reports of quality department.

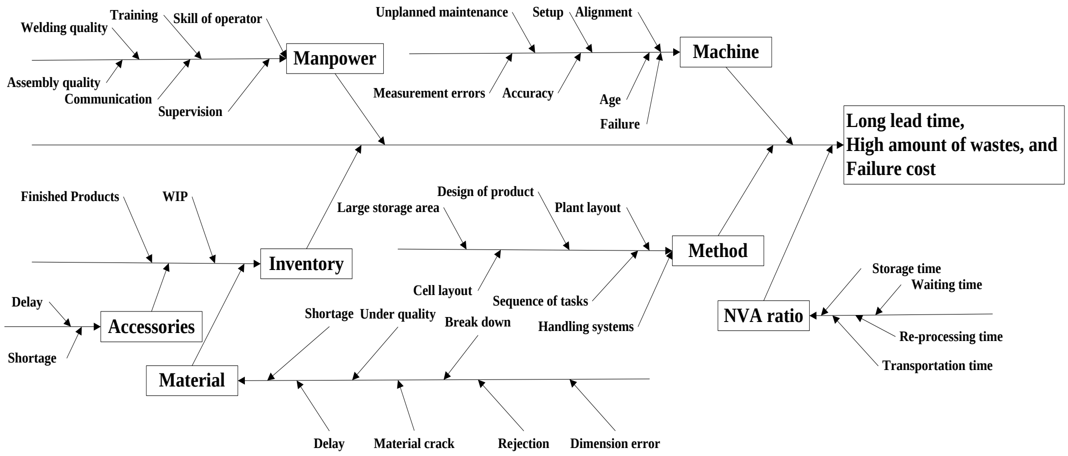

Fig.2. Cause andeffect diagram of the problems

The causes and their effects were obtained from respondents while interviewing them, self-observations and quarterly reports of quality department. The detail description of the diagram is discussed here below. Long time to deliver the product is caused by WIP times, delays and shortages of raw materials and accessories, doing non-value added activities (storage time, waiting time, re-processing time and transportation time), setup times, and unplanned maintenance. Fig.2 shows that failure of costs lies due to the large lead time and high amount of wastes. Meanwhile study observation also indicates in parallel that manpower and machine consumption is more over here makes unfit to the production during welding unskilled operators, less quality used in assembly lining subsequently measurement errors affects accuracy level of findings and it causes due to lack of supervision directly involved. Secondary, accessories used during production such as materials, incorrect inventory method and NVA ratio is also not maintained may causes the failure in production. To review of shortcomings a new model is proposed. The level of wastes in the processes is high as shown on Figures 4, 5 and 6, and the data investigated at Figure 3. Different causes were mentioned for this effect. As already known, wastes are categorized under eight groups and each waste group has its own causes. Over production is caused by product design problem, miscommunication, and negligence of supervision. When the product is out of customer's specification due to design error, misunderstanding and defects due to supervision weakness, the customer couldn't accept the product but the company manufactures another product with the required specification. This leads the company to wait until other customer buys the previous product. Waiting or delay of processes is also caused by many factors such as storage time, waiting time, re-processing time, transportation time, delay and shortage of raw materials and accessories, WIP inventories, machine setup, machine failure, unplanned maintenance, luck of skill of operators, supervision negligence, plant layout, cell layout, and sequence of tasks.

Checklist of wastes found at the manufacturing process of the product

The checklist of eight types of wastes and proposed actions which should be taken to minimize wastes is given on Table 6. All eight types of wastes are existed but with different levels.

Table 6: Checklist of the eight types of wastes

Waste type	Type of Waste Exists Here (√)	Type of actions which should be taken to correct it:		
		Capital investment (√)	Supervision attention (√)	Further study (√)

Overproduction	√		√	
Transportation	√	√		
Inappropriate process	√		√	
Motion	√			√
Waiting	√		√	
Inventory	√		√	√
Defects	√	√	√	
Underutilization employees	√		√	√

From Table 6, capital investment is needed to reduce the level of wastes due to transportation and defects of products. Transportation is occurred due to stations established far apart each other, and to solve this problem, re-installation of machines and equipments at the appropriate area is recommended with some capital investment. Defect of products are caused by supervision negligence and machineries capacity to manufacture with the required accuracy. Improvements in defects of products caused by machineries efficiency needs investment to calibrate or change machines at all. Supervision attention is highly required in reduction of all wastes except transportation and motion waste categories. However, further study should be conducted on waste types of motion, inventory and underutilization of employees for further improvements. For example, according to [21], the level of inventory between processes should be zero and to achieve this target further study on this area should be conducted. The eight wastes ranking algorithm based on the results gained on the data collected as shown at Table 7, is determined according to the procedures followed below. Let 5 be a rate for high waste; 4 be a rate for medium waste; 3 be a rate for low waste; 2 be a rate for any other suggestion; and 1 be a rate for non-responding decision. Then, it is possible to calculate the total amount that each waste accounts based on the respondents answer multiplied by the rates given above as 5, 4, 3, 2 and 1. For an example, take an inventory so that 14 respondents said high waste of inventory, 11 respondents said medium waste of inventory, 3 respondents said low waste of inventory, no one said any other, and all respondents were responding. Thus, it can be calculated as: Inventory= 14x5+11x4+3x3+0x2+0x1=123. In the same manner, it is also possible to calculate the level of all the remaining wastes. Then, the results were summed and each waste's level of percentage was calculated by dividing level of occurrence of that waste with the total level of occurrence of all wastes. As a result, the result is summarized on Table 7.

Table 7: Wastes and their levels (Source: Data from respondents)

S/N	Type of Waste	Level of Occurrence	Level of percentage
1	Inventory	123	14.44
2	Waiting	117	13.73
3	Over production	87	10.21
4	Transportation	110	12.91
5	Inappropriate processing	98	11.50
6	Motion	100	11.74
7	Defect	104	12.20
8	Manpower utilization	113	13.26

The eight wastes algorithm is shown on Figure 3.

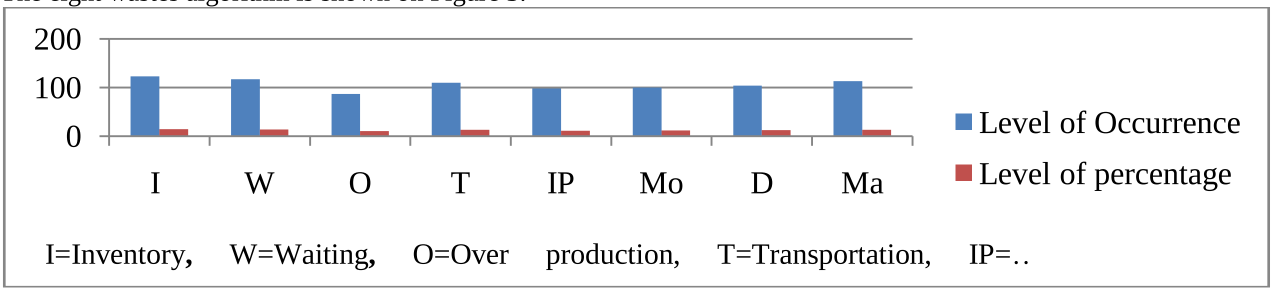

Fig.3.The wastes algorithm using column chart

The chart shown on Fig. 3 indicates that inventory is the first serious problem of waste in the processes of the company. Waiting during processes and manpower utilization are second and third ranked waste problems next to inventory, respectively. Transportation is also the forth ranked waste problem. Thus, the future state value stream map has considered these serious issues as main target to be achieved while designed it. Different types of wastes with different levels exist in the processes of manufacturing the product as shown above. The data shown at Table 6 proves this fact. The general comments on the eight types of wastes exist in the manufacturing of the product are discussed below.

Overproduction: The Company follows make-to-order principle. Different customers order the product and the company manufactures and delivers the required product. However, sometimes the company manufactures products beyond the required amount because of information barrier. Not only this but also design changes due to misunderstanding is another factor for which the customers couldn't accept the product with the design out of their specifications. As a result, the extra products stay at the company for a long time, which is a great lost. This waste happens sometimes as of the information from the company.

Fig.4. Products manufactured out of customer specifications

Transportation: This is the movements of parts (components) and all types of material handlings within the production line. The total distance covered during manufacturing of dry cargo trailer is about 800 meters. This long distance is due to travelling in a backtrack type of movement while manufacturing of the product. Even, the auxiliary shop used to fabricate accessories is far away from the assembly cell at 150 meters, but these accessories might be fabricated at fabrication shop and assembled there. To minimize this transportation distance and the time to the possible value, capital investment is needed to install the auxiliary shop around the plate form assembly cell (shop two).

Inappropriate process: When the products are checked for their quality, some of them might not be good; as a result reviewing and re-planning is mandatory. Due to this, over processing occurs at the process. This waste occurs while manufacturing the product even if it is rare.

Motion: This is also another waste category which is unnecessary movements of workers to reach to equipments, for looking parts or components and tools during manufacturing of the product. Some of the tools and parts lay on the floor as well as corners of the cell without proper arrangements. This makes difficult to find the right tools and parts at the right time on the right place. Thus, unnecessary movements are experienced by operators for finding the required tools and parts. As a result of this, much of the time is consumed and elongates the lead time.

Waiting: Waiting occurs due to machine and equipment downtime, processing of orders and materials and/or parts transferring, shortage or delay of raw materials and accessories, machine setup, unplanned stoppages due to machine breakdown and interruption of power. The longest time of waiting for receiving the raw materials and accessories from the suppliers is about three months, whereas the longer time of waiting for transferring prepared materials from preparation shop to fabrication and auxiliary shops is 8 days. On Figure 5, semi-processed products are waiting axle accessory until purchasing process is finished. Purchasing of materials and accessories takes three months for searching of suppliers since no constant suppliers, and rejection of promises to deliver the materials and accessories because of price increment after agreement has been made.

Fig.5. Waiting of semi-processed products due to lack of accessories

Inventory: It is a waste related to raw materials and accessories, work-in-progress (WIP), and finished products in the process considered. The company sometimes purchase large amount of raw materials and accessories to be safe from problems of shortage and/or delay of them by assuming as orders will come soon. Unfortunately, the demand of the product might not be as an expected so that raw materials and accessories will stay for a long time with holding money as well as space. The WIP inventory is another waste occurred in between processes due to factors mentioned in waiting waste category. The finished products inventory is also happed due to quality checking, late coming of customers to receive products, and re-working of products because of quality problems.

Fig.6. Work-in-progress inventory at fabrication shop two

Defects of product*:* Defective products are due to scratches, cracks, dimension errors, design errors, poor welding and assembling, and so on of the product. The defective products are either reworked or scrapped as the information from the quality department. Thus, it is not difficult to conclude that the company has lost due to defects of products.

The major causes and costs of internal failures are:

- Rework or reject of parts or semi processed parts due to poor welding quality, dimension errors, poor assembly of parts, and appearance of crack;
- Rejection of material due to under quality;
- Replacement of pieces or parts due to under quality;
- Man power cost for doing activities;
- Machine hour cost; and
- Consumable cost like power consumption.

The amount of cost of each quarter is given in birr and percentage they account from the total cost. Fig. 7 shows the amount of cost in each quarter graphically. Thus, the figure shows that the amount of cost incurred due to failures of the product is significant and attention should be given to reduce it.

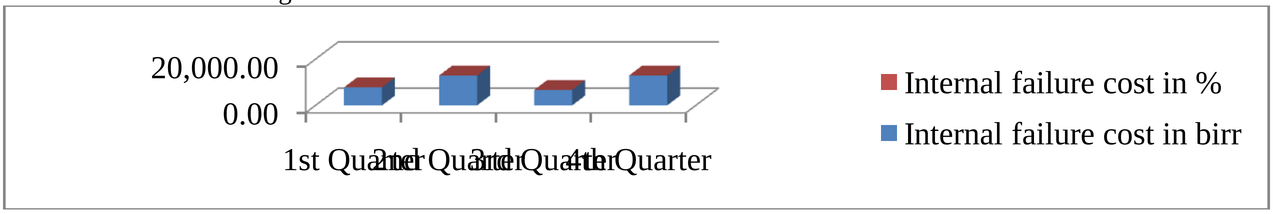

Fig.7. Charts of costs incurred due to internal failures of the product

Underutilization of manpower: Manpower utilization for manufacturing of the product is so poor. There are many employees who are idles and doing with less capacity. Even the time some employees spend for doing tasks is less than the time they spend for doing nothing. The number of workers assigned to a certain task is not also based on the number of manpower required to that task. So, properly studying and re-assigning of employees is a critical issue to be successful in terms of manpower utilization.

Current State Value Stream Map

The current state value stream map was drawn based on the data obtained from the company as shown in Fig. 8 below. The map consists of both material and information flows from one process to another process including number of operators, WIP times, changeover times and times taken to accomplish each process, and so on. This map was drawn for identifying existing wastes with opportunities of improvement and used for mapping the future state value stream with certain improvements on limitations and challenges, and of course have been done.

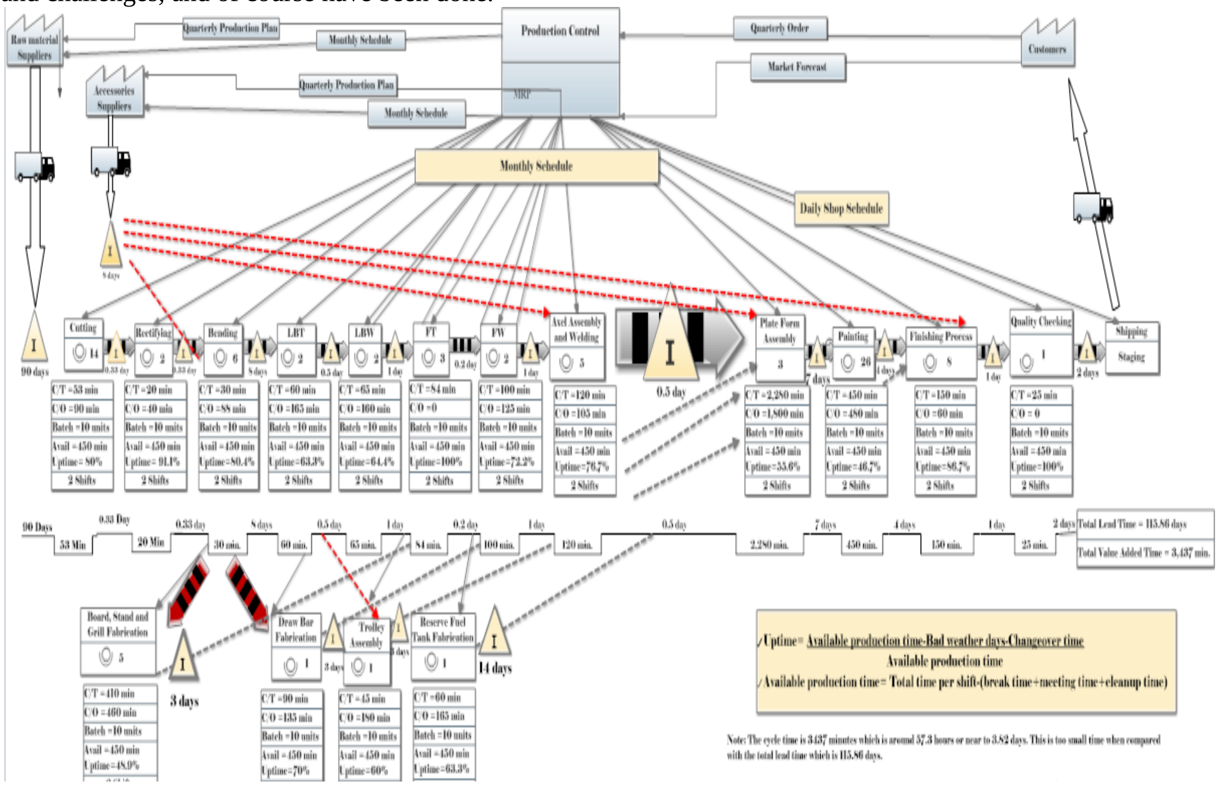

Fig.8. Current State Value Stream Map (CVSM)

Fig. 8 shows the current state value stream map for manufacturing of dry cargo trailer with many operations. It includes the following information:

- Customer requirements communicated electronically and manually as market forecasts and quarterly orders respectively;
- Production control calculates monthly requirements using material requirements planning (MRP) software system and delivers a printout of schedule to each process;
- Raw materials and accessories requirements communicated to supplier through quarterly production plan and monthly schedule using both electronic and manual systems respectively;
- Raw materials and accessories are scheduled to be delivered once per three months by suppliers to satisfy quarterly production requirement;
- Twenty two discrete processing steps (cutting + rectifying + bending + painting + 9weld + 9 assembly) are used to produce dry cargo trailer;
- Each operation produces uncontrolled quantities of work-in-process independent of one another due to multipoint scheduling and improper flow of materials and information;
- Changeover time for plate form assembly and welding process is the longest time in the overall process of producing the product, which is 30 hours or 2 days;
- Average machine and operation uptime is 72.5 percent;
- Completed dry cargo trailers are shipped to the customer once per two days;
- Process lead time is 115.86 days; and
- Processing (cycle) time is 3,437 minutes or around 3.82 days by considering two shifts per a day and 7.5 working hours per shift.

In the current state value stream map, it is clearly seen that the total lead time is too much greater than the processing (cycle) time. This is occurred due to the long time consumed because of work-in-progress inventories (because of inspection of the quality of the product, inappropriate work flow, luck of understanding about continuous flow of pieces, etc), non-value added activities performed and materials and accessories delay during purchasing (due to time lost for searching best suppliers because of absence of constant suppliers). So, it is possible to reduce the lead time at least by half by improving times spend for materials and accessories receiving and work-in-progress inventories, in addition to eliminating unnecessary activities. As can be seen on the diagram above (Figure 8), there are WIP inventories between operations and the times for those WIP inventories are too long. This is because the semi-processed parts are transferred from one shop (process) to the next in batches, but according to the fact, the flows of materials (or semi-processed products) and information should be continuous. As per the discussion of Liker (2004), the product flow with value adding processes should not be interrupted (one-piece flow or continuous flow). Of course, the idea of one-piece flow is not possible at once, but it provides a clear direction how to reduce delays and waiting of material transferring. Even if it is mandatory to set up inventory buffers in places where pure on-piece flow is impossible, the focus should still be on reducing the inventory overtime to improve flow. From the current state map, it is also shown that there are activities or processes which could be assigned (allocated) at the same stations with a cellular manufacturing principle. In cellular manufacturing system, activities which can be performed at the same station with the same facility and used as an input for an output are grouped together. This reduces unnecessary movements, transportations and changeover times. So, cellular manufacturing system should be applied in manufacturing processes of the product. Cycle time in below part of above Figure indicates the real time used to accomplish the value adding activities of product during production. In above, changeover time is same as a set up time in the exiting MIE model. The Figure indicates that information flow of materials at various workstation followed by cutting to shipping process takes much individual time.

Future State Value Stream Map

The future state value stream map was designed to achieve higher value added activities with continuous flows of materials and information. In the future state map, the linkage between processes and people is better so that problems surface right away. The work-in-process inventory (WIP) was also considered as one major issue for improvement. Thus, in the To-Be (future state) map, WIP is reduced by eliminating unnecessary delays of processes and activities between operation stations. This results in reduction of the overall lead time or throughput time (time from order receiving to delivery) of the product. The distance travelled during manufacturing of the product was also another target point to be improved. According to value stream mapping principles, this distance should be reduced to a minimum value in order to reduce the time lost due to moving to somewhere, as much as possible. Thus, transportation distance was minimized by grouping activities which could be done at the same station with the existing facilities and space, and capital investment using the principles of group technology. This would reduce machine and process setup times and waiting times in manufacturing processes of the product in addition to reducing distance moved along processes, and facilitating flows of materials and information. A portable welding machine is used for fabrication of boards, stands and grills at auxiliary shop, which can be transported from one place to another easily. For moving and allocating these processes to fabrication shop near to plate form assembly cell, capital investment is required for labor costs and power facilities which will not be more than 5,000 birr. But, for the other processes and activities grouped together which could be done at the same cell (station), capital investment is not a big deal because they can be arranged with the existing facilities and space only without affecting the processes of other products. Facilities include transportation means, machines, equipments, and so on.

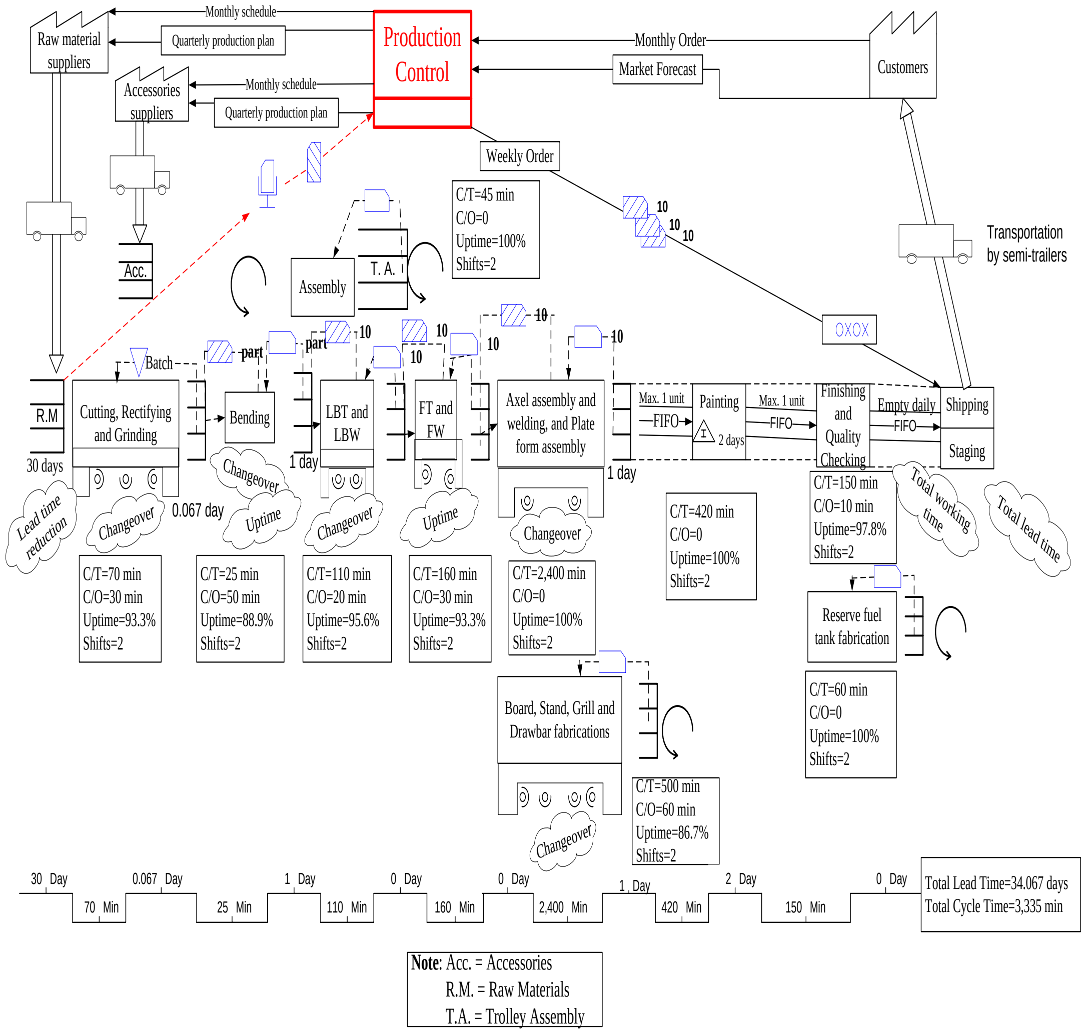

Fig.9. Future State Value Stream Map (FVSM)

To reduce lead time, cost, performance and increase in productivity one another model was proposed. In order to do so, it is proposed that individual workstation during the materials flow was such as cutting, rectifying and bending in one segment, FT and FW together in one unit, LBW and LWT etc. is synchronized. By that, it is found that it not only reduce the cost but leveraged in terms of minimizing lead time and increasing productivity as well. Beauty of this proposed model is assumed it may have first work practice in Ethiopia to make exact identification of materials information flow carried out. It is presumed that it will help out in finding the performance of exact production assembly line too. The future state value stream map has been designed based on the information obtained from the current state value stream map by identifying critical improvement aspects and opportunities. The future state value stream map is shown on Figure 9.

Fig. 9 shows the future state value stream map. It includes the following information:

- Customer requirements are communicated electronically as the market forecasts and manually as monthly order;
- Production control issues weekly orders to shipping department using Kanban (i.e. work instruction) card system [22];
- Raw materials and accessories requirements are communicated to suppliers quarterly through computer, and monthly via manually;
- Raw materials and accessories are delivered monthly by suppliers to a “supermarket” (i.e. controlled inventory used to schedule work at an upstream process);

- Seventeen discrete processing steps (cutting and rectifying + bending + painting + 7weld + 7 assembly) are used to produce dry cargo trailer (reduction of discrete welding and assembly processing steps was due to drawbar fabrication merged with board, stand and grill fabrications, and axle assembly and welding merged with plate form assembly);
- Ten processes are grouped in different processing boxes with a principle of cellular manufacturing system, and combined assembling and welding operations;
- Supermarkets are applied to control the amounts and times of work-in-process inventories;
- Average process uptime = 95.4 percent;
- Completed dry cargo trailer are shipped to the customer once per day;
- Process lead time = 34.067 days; and

Processing time = 3,335 minutes or around 3.71 days.

While designing the future state value stream map, the following major goals were taken into account for which to be achieved.

- Minimizing inventories of materials, work-in-progresses (WIP), and finished goods;
- Developing a chain among processes through a continuous flow;
- Minimizing waste and lead time with existing facilities and an existing product and processing;
- Reducing distance due to a remote location of some activities or processes; and
- Grouping activities which can be done at the same locations with the same facilities.

The manufactured, assembled and welded components of the product supermarkets, withdrawal Kanban, production Kanban, Kanban flows (dotted lines), and signal Kanban are drawn on the future state value stream map (Figure 9). Even though, raw materials and accessories suppliers may not be ready to receive Kanban and supply based on the quantity required, MIE can use withdrawal Kanban to every raw materials and accessories, and send these Kanban to its production control department whenever other raw materials and accessories are used. Grouping of activities were done based on the important criteria of availability of space, similarity of activities in using same machines and other facilities, nearness to the next process, and easily arrangement of cells (with less investment and effort). As can be seen on Figure 9, grouping processes results minimization of distance, easily transportation of parts, reduction of waits and delays, facilitating continuous flow of materials, reduction of setup and changeover times, reduction of WIP inventories, and reduction of manpower requirement. This is a great improvement but it can be improved more than these values if processes flow continuously with zero level of WIP inventories. Table 8 indicates the comparison of the results of the CVSM and FVSM.

Table 8: Results of CVSM and FVSM

Parameters	Current State (Unit)	Future State (Unit)	Change in %age	Remark
Lead time	115.86	34.067	70.6	The improvement obtained is beyond the target set which was to reduce at least by half.
Cycle time	3,437	3,335	2.97	Obtained by merging activities
Average Uptime	72.5	95.4	24	Obtained by minimizing setup times
Operators	82	70	14.6	Leaving inactive employees in the new value stream
NVA/VA time ratio	30.33	9.18	69.73	The improvement is obtained by focusing on value adding time and minimizing non-value adding time.

The change in percentage is calculated as:

$$\frac{Maximum\ value - Minimum\ value}{Maximum\ value} x100$$

7.0 Conclusion

The research is conducted at MIE plc which builds bodies of eight automotive products. The company is suffering from some major problems, and losing many advantages. To overcome and get rid of the major problems so that to bring an improvement on the overall process, the company has implemented some improvement tools and techniques such as quality management system (QMS), kaizen, quality circle, and 5S; however, the required change didn't come. So, value stream mapping technique is found suitable to bring the required improvements by identifying major wastes and reducing those wastes encountered the company in manufacturing of dry cargo trailer. As a result of reducing of wastes, the delivery time and production cost will also be reduced. Improper utilization of machineries has negative consequences on the production, productivity and production cost leading to loss of revenue. Based on the detailed analysis and overall result of literatures, data survey and case study, the following conclusions have been drawn:

- The company is facing with major problems of long delivery time, high production cost due to additional internal failure costs, and occurrence of all wastes in different levels. These problems have been identified after mapping the existing value stream of dry cargo trailer and analyzing it.

- The major problems such as long lead time (115.86 days), high wastage of resources and considerable failure cost have been analyzed using cause and effect (fish bone) diagram. Thus, the result indicates that there are many factors causing the effects from materials and accessories, inventory, machine, method and non-value adding activities perspectives.
- Value stream mapping is found as an appropriate tool of identifying and reducing wastes in the overall process of manufacturing of the product, and improving the production cost, quality, and processing as well as delivery times.
- The machineries utilization to manufacture the products has also been analyzed, and the result shows that some of the machineries are operating under their capacity, and others are idle. This is happened due to long time work-in-progress inventory in between operations, frequent failure of machines, and free from process allocation. Other resources (manpower, raw materials and time) were not efficiently utilized.
- There is no clear flow of information along processes from request receiving to delivering the product. One supervisor knows only about the process he/she is dedicated, but doesn't have any information about other processes. This is because of information flows from production control to each process or station only.
- To make a media of communication that everyone in the company can easily understand the whole process, and get improvements on limitations, the value stream mapping tool was applied. Thus, the future state value stream map was drawn based on the existing state map which improves the overall process of the production line.

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