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LEAN IMPROVEMENT FOR PANTOGRAPH JACK PRODUCTION PROCESS USING VALUE STREAM MAPPING

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ABSTRACT

The objectives of this research are to study the current process and improve the production process of pantograph jack by using Lean manufacturing techniques. The Lean tool used is Value stream mapping (VSM). The study starts with collecting data from the upstream to downstream to create a Current-state VSM to identify wastes and problems. The first problem was the low efficiency of the production process due to the high lead time of 7 days 8 hours. The ratio of value-added time to the lead time was only 0.026%. The next problem was overproduction because the cycle time is 69.54 seconds/piece while the takt time is 140.15 seconds/piece, which is 46.62% of the takt time, resulting in the early stoppage of the production line to prevent over inventory of finished products. After identifying the problems, the next step is to define production process improvement approaches by creating a Future-state VSM. The tools for the improvement included the Kanban system, Supermarket, Line balancing, and Cellular manufacturing then a simulation model of both current and future states was created to compare the results before and after the process improvement. The result from the simulation shows that the total lead time was reduced to 4 hours 39 minutes or a decrease of 97.54% from the current state. The ratio of value-added time to the lead time was increased to 1.304%, which is 49.39 times more than before the improvements, and the cycle time was increased to 133.02 seconds/piece, which is 94.91% of the takt time.

Keywords: lean improvement,value steam mapping,computer simulation,line balancing.

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1. INTRODUCTION

Nowadays, the business sector and the manufacturing industry are in highly competitive environment [1]. Companies need to develop and change consistently in order to meet the needs of customers in terms of defect-free quality and speedy delivery. An important operational strategy of applying Lean Manufacturing concept and its techniques to the organization and production process is the approach to respond to the business needs and create satisfaction for customers. The main concept is to increase production efficiency by reducing wastes that occurs in the production process [2].

Value Stream Mapping (VSM) is one of the most important Lean tools in manufacturing process analysis to provide an overview of the entire process from upstream to downstream and illustrates the wastes associated in the process [3-4]. It can also distinguish value-added activities and non-value-added activities, which leads to planning to develop efficient production processes by eliminating wastes that hinder the continuous flow of the value stream and increasing lead time [5]. The computer simulation-based model is also used to simulate the production process from the Current VSM to analyze the efficiency of the production process and simulate the situation after the wastes of production process are removed as the Future VSM, the operational results of current and future are compared to highlight the improvement.

This work uses a case study of the pantograph jack production process, which is one of the products of a large automotive-parts manufacturing company that is the main supplier for a group of automotive assembler companies.

2. LITERATURE REVIEWS

2.1 Lean Manufacturing

Lean strategy is a multi-dimensional approach that encompasses a wide variety of management practices focusing on quality and supplier management, identifying and eliminating waste through continuous improvement [6]. Lean is also associated with having minimal work-in process inventories and production lead times while still allowing reaction to pull strategies given customer demand through such a mechanism as Just-In-Time practice.

Waste minimization is one of the core concepts of being Lean. The Lean approach essentially defines waste as anything that does not add "value" to the customer. Waste is not just excess inventory, defective parts, or excess production capacity but also unused or redundant processes, financial and human resources [7-9]. Waste minimization refers to processes that seek to continuously reduce waste and exploit the most efficient use of scarce resources. [10-11].

2.2 VSM

Value stream mapping (VSM) is defined as a lean tool that employs a flowchart documenting every step in the process. Many lean practitioners see VSM as a fundamental tool to identify waste, reduce process cycle times, and implement process improvement [12].

ARPN Journal of Engineering and Applied Sciences

VSM is a workplace efficiency tool designed to combine material processing steps with information flow, along with other important related data. VSM is an essential lean tool for an organization wanting to plan, implement, and improve while on its lean journey. VSM helps users create a solid implementation plan that will maximize their available resources and help ensure that materials and time are used efficiently. It's often done before an improvement project to determine the current state, followed by a future-state proposal using an altered version of the map to determine the benefits of the proposed changes.

There are a number of common icons used in value stream maps, but icons can also be customized to best serve a value stream map. Icons help distinguish different elements of a product line from another. For example, different arrows should be used to distinguish between product and information movement. Figure-1 below contains commonly used icons in value stream mapping [13].

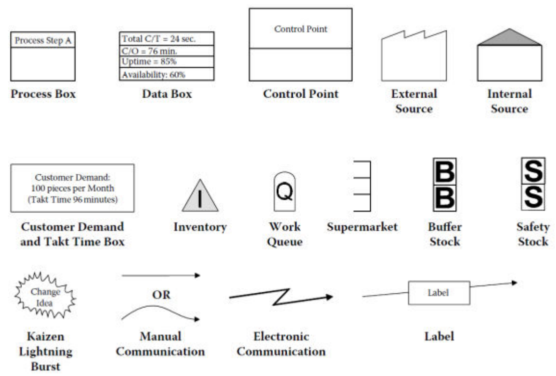

Figure-1. Common icons used in VSM.

2.3 Computer Simulation in VSM

The main reason to perform value stream mapping in simulation [14]:

- To Reduce the cost of data collection by reducing the number of describing processes using predefined logic blocks,
- To decrease the effort by analyzing through automated modules.

With computer simulation it is possible to explore the dynamic flow effects of values which remain hidden in the static mapping of value chain on paper in a case of conventional VSM. Traditional static value flow analysis is expanded to include a critical time element of stock availability. Simulation shows the dynamic fluctuations in daily production due to batch size, setting procedure, product charges, or other faults. The main output of VSM is the image representation of the flow of values and a comprehensive view of the production of selected representative. Mapping provides a credible view of narrow production sites, the reasons for possible losses and inefficient production or storage systems.

3. MANUFACTURING PROCESS

A case study process is pantograph jack production, as an outline process chart is presented in Figure-2 and the finished product is presented in Figure-3.

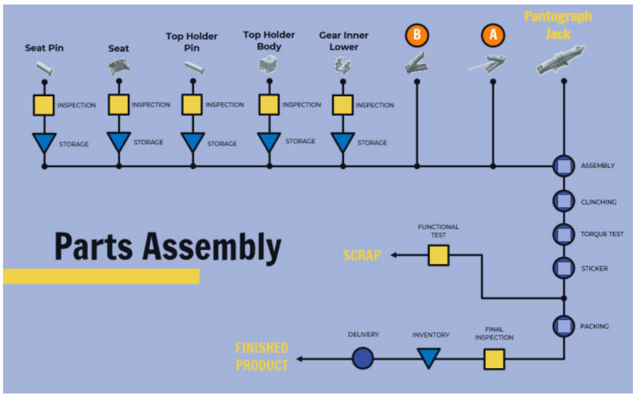

Figure-2. Outline process of pantograph jack.

Figure-3. Finished pantograph jack.

The production line starts from Part A and Part B assembly in station 1 and 2, then all parts with seat pin, seat, top holder pin, top holder body and gear inner lower are combined in caulking screw process in station 3. After the clinching assembly is operated in station 4, the final inspection is performed to confirm the quality of finished product.

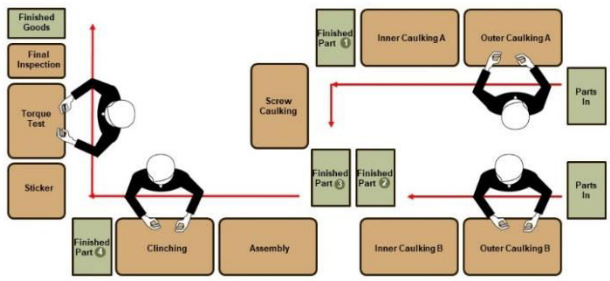

Figure-4. Layout of working area.

These operations are performed in small area of factory which have four operators working in five stations. The cycle time of each station and process data associated in each station are illustrated in Table-1.

VOL. 18, NO. 10, MAY 2023 ISSN 1819-6608
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Table-1. Process data of working stations.

Station / List	Caulking PartA	Caulking PartB	Screw Caulking	Assembly & Clinching	Sticker & Inspection
No. of Operators	0.5	1	0.5	1	1
Processing time (sec.)	36.42	36.17	48.77	63.48	69.54
Changeover time (sec.)	600	600	600	600	600
Machine (%Uptime)	96.88	96.88	96.88	96.88	96.88
Work in process (pcs.)	10	26	2	1	400
% Reject (%)	0.48	0.45	0.33	1.20	1.95

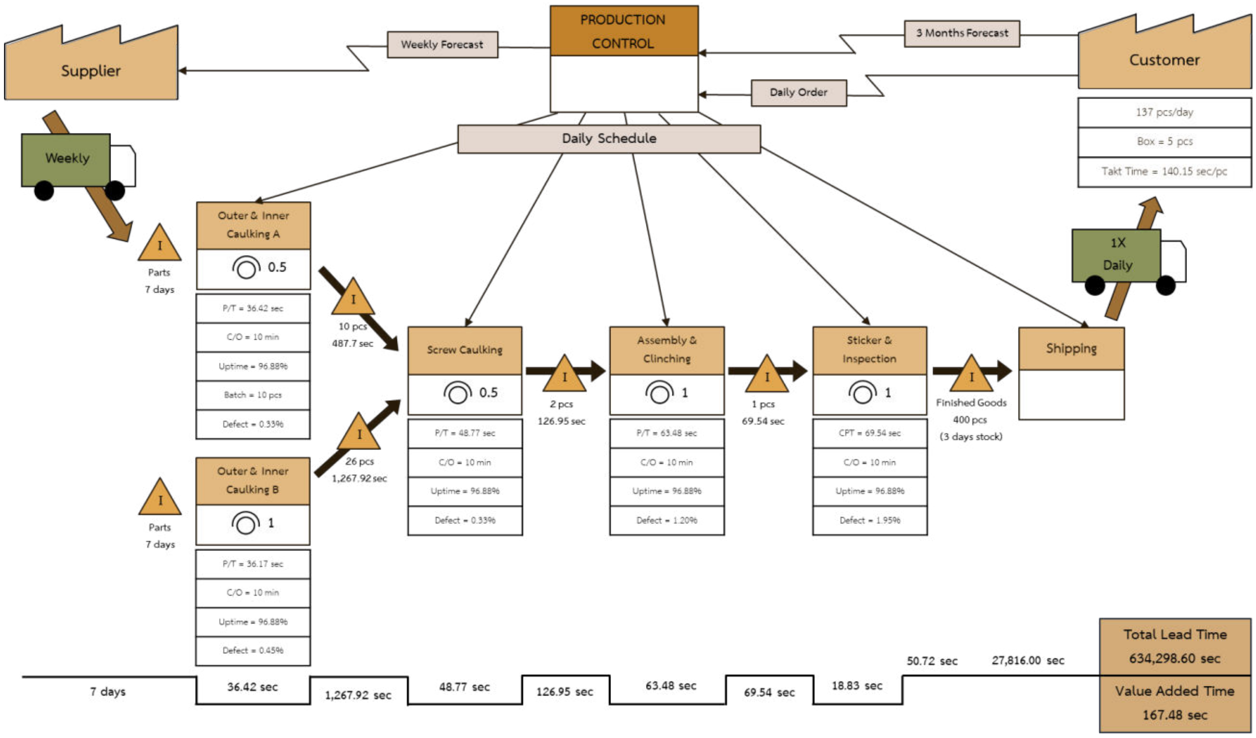

Figure-5. Current VSM of production line.

4. DEVELOPMENT OF CURRENT VSM AND ANALYSIS

4.1 Developing Value Stream Mapping

From the pantograph jack manufacturing process described in the previous section, a value stream mapping can be drawn based on the data and shop floor observation, which are depicted in the Figure-5.

On the right corner of VSM, Customer provides three months forecast and a daily order by electronic data, which is about 137 pieces a day orthe takt time is 140.15 seconds per piece. The Production control department is the center to plan and distribute a daily production plan to each production units including place the order of raw material for production. The stock of raw material is usually maintained to be used for seven days. The production process can be separated into five working stations. The production keeps the stock of finished products for three days usage in shipping area and send to customer in daily basis. The value-added time is 167.48 seconds in manufacturing while the total lead time is very long in about eight days.

4.2 Identify Waste in Current Value Stream Map

The major waste is overproduction result from the takt time of 140.15 secs is much higher than the actual cycle time of 69.54 secs. The line balancing methodology can be used to deal with this too many operators and stations causing low percentage of human utilization and low cycle time. The analysis of problem and causes are presented in cause and effect diagram in Figure-6.

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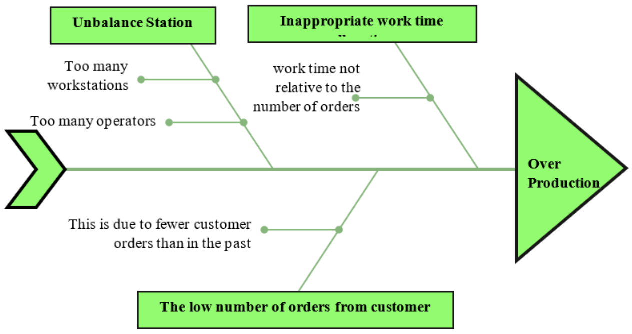

Figure-6. Cause and effect diagram of overproduction.

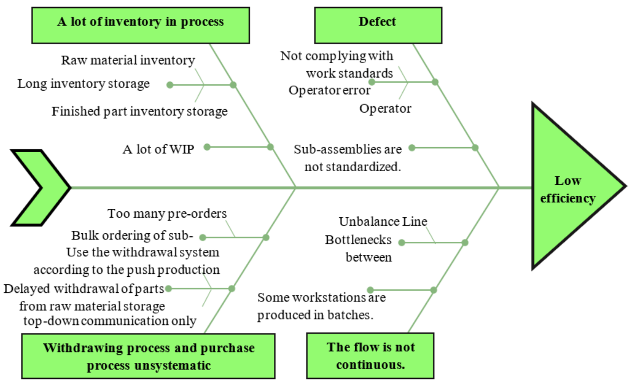

Figure-7. Cause and effect diagram of low production efficiency.

The overall next problem is the low efficient production system. There are a number of wastes that cause this significant long lead time while manufacturing cycle time is just about 167.48 sec. Such causes are high inventory level in both raw material and finished product, production planning policy and unbalanced production-line. The detail analysis is presented in Figure-7.

4.3 Computer simulation for Current Value Stream Map

Arena software is used for coding current VSM, and the program is shown in Figure-8.

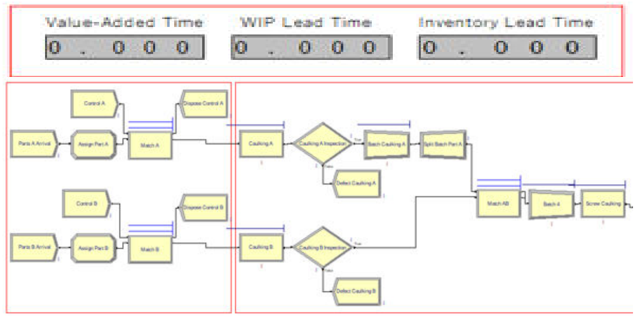

Figure-8. Example of simulation program.

The value-added time, production lead time, cycle time and WIP are recorded along simulation testing for eight hour working day in seven days consecutively in order to yield the current operational performance.

5. DEVELOPMENT OF FUTURE VSM

5.1 Improvement of Value Stream Mapping

From the two major problems in section 4.2, the improvement concept of lean is applied to produce the lean production. The summary of ideas and solutions is presented in Table-2.

The line balancing technique as a tool is implemented to set the suitable number of work stations. The calculation of number of work stations is performed as follow;

No. of stations = total process time/talk time
= 218.21/140.15
=1.56

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ARPN Journal of Engineering and Applied Sciences

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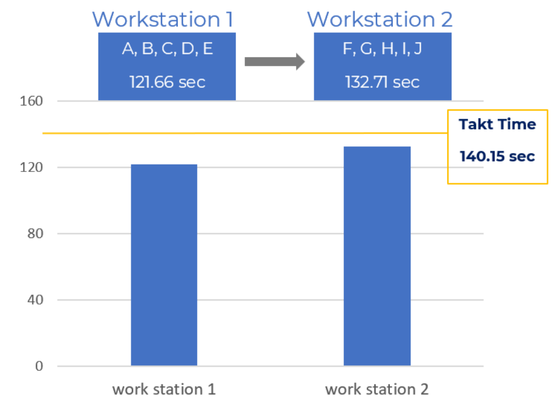
Table-2. Analysis of root causes and solutions.

Problem	Root cause	Type of waste	Solution
Low production efficiency	Long time to keep raw material inventory	Unnecessary Stock	- Use the Kanban system and supermarkets to order raw materials and stock raw materials daily for orders from customers.
	Finished part inventory storage period	Unnecessary Stock	- Use the Kanban system and supermarkets to order raw materials and stock raw materials daily for orders from customers.
	A lot of Inventory in process	Unnecessary Stock	- Use One-Piece flow System -Use a cellular assembly line
	Too many pre-orders	Unnecessary Stock	- Switch from Push System to Pull System
	Delay withdrawing part	Idle Time or Delay	- Use the Kanban system to withdraw raw materials from the raw material stock.
	Unbalance Line	Idle Time or Delay	- Balance all production lines.
	Some workstations are produced in batches.	Idle Time or Delay	- Use One-Piece flow System.
Over production	Too many workstations	Inefficient Process	- Arrange production lines workstations suitable - Use a cellular assembly line
	Too many operators	Inefficient Process	- Use a cellular assembly line



Task	Detail	Predecessor Task	Time (sec)
A	Outer Caulking (A)	-	17.94
B	Inner Caulking (A)	A	18.78
C	Outer Caulking (B)	-	15.07
D	Inner Caulking (B)	C	21.10
E	Screw Caulking	B, D	48.77
F	Assembly	E	30.64
G	Clinching	F	32.84
H	Sticker	G	18.83
I	Torque Test	H	39.03
J	Final Inspection	I	11.69

Figure-9. Work combination table for two stations.

The suitable number of stations from line balancing is two stations, therefore the standardize work combination table is used to separate work process into small elementary works, which are rearranged elementary to fit the takt time of two stations as shown in Figure-9.

The new layout for work place is designed in U shape to minimize the motion of operators as presented in Figure-10. The wastes, overproduction, inventory, waiting time, WIP and working space are also reduced. It be noted that before re-layout and balancing, the number of stations is five stations and working with four operators, then the only two stations with two operators efficiently meet the customer demand resulting in elimination of overproduction problem and minimal of production cost.

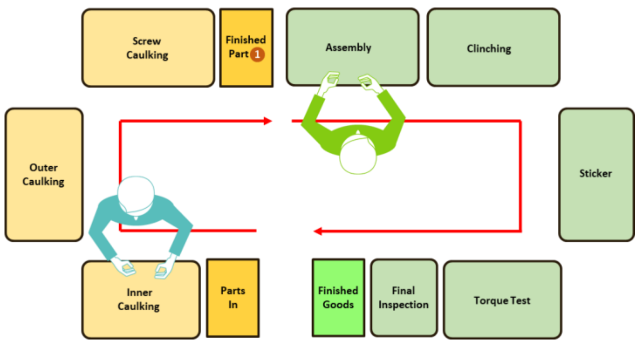


Figure-10. New layout of working area.

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ARPN Journal of Engineering and Applied Sciences

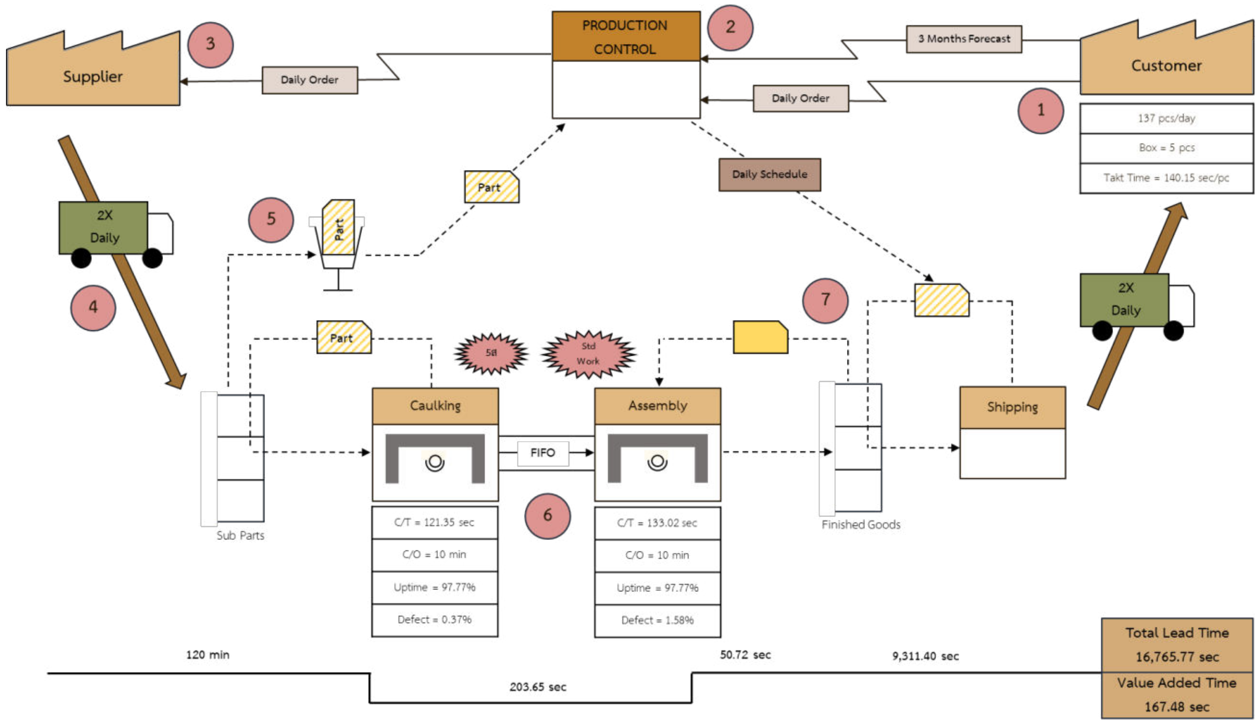

Figure-11. Future VSM of production line.

5.2 Develop the Future VSM

On the future VSM presented in Figure-11, the demand of customer is 137 pieces a day, which is equal to takt time of 140.15 sec. One of significant improvement of production control is changing the current push system to the pull system by applying supermarket concept in raw material store and finished product store. The inventory of both stores is controlled by using Kanban card to communicate customer demand and place production order to constant inventory level. The stock of raw material from one week usage is limited to 120 minutes usage by mean of these Kanban and reduction of lead time from supplier by increasing delivery frequency to twice a day shipment.

In manufacturing process, the cycle time is changed from 69.54 Sec to 133.02 sec. to appropriately meet to the takt time at 140.15 sec. causing the remove of overproduction problem. The cost of production is also markedly reduce due to number of operator used in the process decrease from four operators to two operators in only two working station. In overall from the future VSM, the total lead time of 16,765.77 sec. (less than 1 day) is much less than that of current VSM, which is about eight days.

5.3 Comparison of Process Performance of Current and Future VSM

The computer-based simulation is applied to evaluate the process performances according to the process parameters used in both current and future VSM. The run is set as eight hours working in seven consecutively working day and the results are showed in Table-3.

Table-3. Comparison of process performances.

Process Performance indicators	Current state VSM	Future state VSM
Lead time (sec.)	633,191.37	15,603.76
Value-added time	167.16	203.46
Waiting time per piece (sec.)	9,076.46	0.27
WIP (pcs.)	418	62

The performances of future VSM shows the remakedly improvement compared with those of current VSM. The result indicates that the lead time of current 633, 191.37 sec. is reduce to only 15603.76 sec. because of the lower level of raw material, WIP and finished product of the new future VSM.

6. CONCLUSIONS

One of the important Lean tools applied to this work is Value Stream Mapping (VSM), which helps to visualize the process from upstream to downstream flow. To create a value continuous flow of process, a value stream mapping is divided into two steps. The first step is to create a value stream mapping of the current process situation to identify the wastes that occur during the process and distinguish value-added activities from non-value-added activities. The second step based on the removal of wastes, the future process is developed as a future VSM, which provides an overview of the ideal process after process improvement using lean tools. A case study of the pantograph jack production process is used to elaborate application of VSM and Lean tools for process improvement in this project. After the future VSM is developed, the both process performance of current and future VSMs are compared by using advancement of computer-based simulation software to present results of notable improvement.

The current production line consists of five working stations with four operators. Such processes are part A and part B assembly, screw caulking, final assembly and clinching and final inspection. From the analysis of the current VSM, it is found that the total lead time is 634, 298.60 sec., while the value-added time of manufacturing process is only 167.48 seconds due to the high inventory level of raw material and finished products. Another major waste is overproduction problem, since the actual production cycle time of 69.54 sec. is much lower than the takt time of 140.15 sec. A set of lean tools are used to eliminate these wastes and propose the future VSM. By line balancing and cellular concept of the manufacturing process, the five working stations are reduced to only two working stations with the cycle time of 133.02 sec., which is suitably fit to the talk time. It should be noted that the cost of production is also reduced by decreasing number of operators and working area. For Long total lead time problem, the pull system is used as a prime production planning method to control the level of inventory for raw material and finished products including WIP. The supermarket concept is set at the store of raw material to keep the level only 120 min usage and at the store of finished product. The daily production is run on using Kanban card to control the inventory level and smooth production order. The ideal production process as shown in the future VSM is constructed based on applying these Lean tools to eliminate wastes.

The comparison of process performances between current VSM and future VSM is carry out. Computer-based simulation software, ARENA, is used to simulate the processes by running the production of eight hours a day for seven days consecutively. On the future VSM, the result shows that the total lead time is only 16,765.77 sec., which is much lower than that of current VSM. The ratio of value-added time to the lead time was increased to 1.304% from 0.026% in the current VSM and the cycle time of the future VSM is increased to 133.02 sec., which is 94.91% of the takt time. It is clearly that the Lean manufacturing as operational strategy could be used beneficially in this case study, thus the VSM and others lean tools can be applied properly to remove the wastes and to enhance the creation of the value flow in manufacturing.

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