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Reduction of Lead Time Using Lean Techniques

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Abstract
The main goal is to reduce the time delays caused in manufacturing of hydraulic excavators which can be accomplished making and executing powerful and proficient procedures in each of its line in their business. For this purpose lean tools are used as lean focus on continuous improvement and reduction of waste. VSM is used to serve the purpose of customer by eliminating the non-value added activities and help in value creation process with minimum lead time. The study was carried out on production process of pivot pins which are used in manufacturing of excavator machines of different specifications. By fixing production schedule and using a lean tool such as VSM, lead time was reduced which in turn reduces the cost of the product.

1. Introduction

Lean manufacturing is the systematic elimination of waste. As the name implies, lean is focused at cutting “fat” from production activities. It has also been successfully applied to administrative and engineering activities as well. Although lean manufacturing is a relatively new term, many of the tools used in lean can be traced back to Fredrick Taylor and the Gilbreths at the turn of the 20th century. What Lean has done is to package some well-respected industrial/manufacturing engineering practices into a system that can work in virtually any environment.

The core of Lean is based on the continuous pursuit of improving the processes, a philosophy of eliminating all non-value adding activities and reducing waste within an organization. The value adding activities are simply only those things the customer is willing to pay for, everything else is waste, and should be eliminated, simplified, reduced or integrated. Wastes are unusually grouped into the following eight categories: overproduction, motion, inventory, defects, waiting, transportation, extra processing, and underutilized people. Toyota practices an approach, which is also termed as Toyota Production System (TPS). This involves achieving ‘More and more with less and less”. This methodology is known as Lean Systems.

Lean Manufacturing, simply defined, is a method of doing more with less. Specifically, Lean Manufacturing is producing high quality products with minimal floor space, work-in-process (WIP) inventory, finished goods inventory, material movement, non-value-added activities, and human effort.

1.1Elements of Lean manufacturing

- Quick change Over
- **Value Stream Mapping**
- 5S
- Total Productive Maintenance (TPM)
- Kaizen
- Kanban
- Six Sigma
- Just-in-Time (JIT)
- Cell Manufacturing

1.2 Lean Thinking: The 5 Principles are:

1. Specify value from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
3. Make the value creating steps occur in tight sequence so the product will flow smoothly towards the customer.
4. As the flow is introduced, let the customers pull value from the next upstream activity.
5. As the value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue until a state of perfection is reached in which perfect value is created with no waste.

1.3 To realize this, Value Stream Mapping is a tool!

1.3.1 Value Stream Mapping

1.3.1.1 Value

Value is the inherent worth of a product as judged by the customer and reflected in its selling price and market demand. The producer through a combination of actions creates the value in a typical product, some of which produce value as perceived by the customers and some of which are merely necessary given the current configuration of the design and production processes. The objective of lean thinking is to eliminate the latter class of activities while preserving or enhancing the first set.

1.3.1.2 Value stream

A Value Stream is all of the actions, both value-creating and non-value creating, required to bring a product from concept to launch and from order to delivery. These include actions to process information from the customer and actions to transform the product on its way to the customer.

Value Stream Mapping**:** It is drawing a visual representation with pen and paper of every process involved in the material and information flows, to scrutinize business processes from beginning to end and, highlighting mainly, bottlenecks and thereby, sources of waste.

1.3.1.3Value stream map

It is a simple diagram of every step involved in the material and information flows needed to bring a product from order to delivery.

Current State Map**:** It follows a products’ path from order to delivery to determine the current conditions. It shows work processes asthey currently exist**,** to understand the need for improvement i.e. change and where the opportunities lie for the same, to impact the overall production.

Future State Map**:** It deploys the opportunities for improvement identified in the current state map to achieve a higher level of performance at some future point. It to show how things should work for best competitive, namely:

- Reduced lead time and Work-in-process.
- Improved product quality and space utilization.
- Reduced rework/scrap and inventory levels.
- Reduced indirect labor costs.

In some cases, it may be appropriate to draw an Ideal-State Map showing the opportunities for improvement by employing all known lean methods including right-sized tools and value stream compression. Within the production flow, the movement of the material through the factory is the flow that comes to our mind, but there is another flow of information, that tells each process, what to make or do next. In Lean Manufacturing, the information flow is treated with just as much importance as the material flow. Flow of information is very important, as information has to be passed, so that one process manufactures only, what the next process needs and only when it is needed.

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2. literature Review

A value stream is a collection of all actions (value-added as well as non-value-added) that are required to bring a product (or a group of products that use the same resources) through the main flows, starting with raw material and ending with the customer (Rother and Shook, 1999). These actions consider the flow of both information and materials within the overall supply chain. The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try and eliminate these (Rother and Shook, 1999). While researchers have developed a number of tools to optimize individual operations within a supply chain, most of these tools fall short in linking and visualizing the nature of the material and information flow throughout the company's entire supply chain. Taking the value stream viewpoint means working on the big picture and not individual processes. VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald et al., 2002).

D.RajenthiraKumar and R.Siva (2006), explained the usage of lean manufacturing technique which can be adopted to improve the quality of a product and reduce the cost of production and also deliver the product in less time, this can be accomplished by eliminating all kinds of hidden waste which do not add any value to the product.

Ranjan Raj Urs (2012), explained about how lead time is reduced using lean tools and on time delivery of product to the customers. In this he has used lean tool called VSM the reason for VSM is to give ideal quality to the client through complete worth creation process with least lead time and with implementation of Kanban inventory is reduced.

3. Problem Statement

In a manufacturing industry, the cost of product increases with the increase in lead time which reduces the profit margin. The root causes of the problems are identified and validated. The various causes for longer lead time are as follows: (i) Workers become slow when they are near to achieve target of completing work. (ii) Design modification has to be carried out to increase the productivity. (iii) Excessive movement of workers and poor ergonomics which amounts to excessive lead time. Thus, the problem statement is entitled as “Reduction of Lead Time Using Lean Techniques in Manufacturing of Pivot Pins”.

3.1. Objectives

1) To minimize lead time
2) To reduce manufacturing cost
3) To identify and remove NVA
4) To enhance overall proficiency of the processes

3.2.Scope of the Study

The overall lead time is reduced by using VSM technique and thereby reduces cost of theproduct which in turn increases the profit margin and enhances the company to be a leader in the market.

4 Methodology

4.1Existing System Study

System study is conducted in order to thoroughly understand the working of all the process in the shop floor. Here the machining operations such as turning, tapping, milling, facing, drilling, and chamfering are thoroughly observed and analyzed so that it helps in ensuring the effective utilization of all the resources such as people, process, and equipment. Changes in the shop floor might have a positive or negative effect on production performance, therefore optimal shop floor operation is required toenhance shop floor performance and to ensure long term efficiency of the production process

4.2 Problem Identification

In this step, after keen observations are made and the process are thoroughly studied, we get a clear picture of types of waste and factors which are causing long lead times such as out dated techniques, machinery, designs etc. and also problems associated with raw materialhandling, scheduling. All these factors affect the productivity, efficiency and increase the cost of the product.

4.3 Data Collection and Analysis

In this step each and every operations are thoroughly studied i.e. The steps followed in manufacturing process from start to finish to get the actual routing so that it will give a clear idea about how the processes work.

In data collection stop watch was used to record the time taken for each operations, ten readings are recorded so that average time can be taken out of it and likewise at each operation data is collected. Here the manufacturing of pivot pin is observed that it runs for a week, twice or a month so that actual scheduling can be summarized likewise lead time data was collected throughout the shop floor for manufacturing of a pivot pin which involves operations like milling, drilling, tapping, chamfering, turning from start to finish of the product.

At times to complete the targets of manufacturing of pivot pins the scheduled numbers of operators are increased so that manufacturing is done to meet the schedule dates. Likewise the data on lead time is collected which helps to draw current state map and its implications for improvement and which can add changes to draw the future state map.

4.4 Supply Chain Network of Organization for Pivot Pins

In the supply chain network the raw material is being procured from a supplier located in Pune, Maharashtra. The process used was melting the scrap in furnace to manufacture the required material. The minimum material ordering quantity with supplieris 20 tones and transportation expenses from supplier source to parent company incurred huge cost. Apart from transportation there was Goods and Service Taxes (GST) and the time consumption is more. A thorough analysis is conducted in the market and we found a supplier named VISL (Vishweshvaraiah Iron and Steel) located at Bhadravati, Karnataka which is comparable near. VISL uses iron ore to produce raw material. The main advantage of procurement from VISL is reduction in transportation cost and reduction in procurement time. We can save money on GST (goods and service tax) as we procure the material within Karnataka and material order quantity is 15 tonnes in VISL which is an added advantage as we can save on inventory.

The below flow diagram explains the present and proposed flow process of pivot pins:

Present flow **Proposed flow**

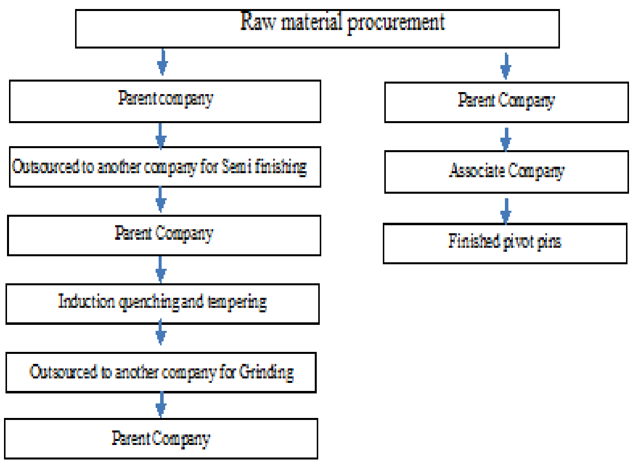

Fig. 1: Present and proposed flow process of pivot pins

4.5Reasons for Long Lead-Time of the Process

- Quality checks for each and every step which goes through the process.
- Frequent transportations of materials after each process
- Excessive movements by workers and poor ergonomics which amounts to excessive leadtimes.
- After break time the worker is less active in completing the work
- Repetitive tasks gets bored and workers become slow in completing the work
- Finished Products are not arranged properly

4.6 Elimination of Non-Value Added Time (NVA)
NVA advert to as waste as indicated by Toyota (Taiichi Ohno). It characterizes waste as something besides the base measure of hardware, materials, parts and working time totallyfundamental to creation or Something besides unquestionably the base assets of materials,machines, and labor required to increase the value of the item.

1) Raw materials at each and every process are kept well in advance as for asrequirement, it eliminates wastage of time to bring raw materials once when required
2) Supervision of workers are conducted so that workers are conscious of their work and eliminates unwanted activities which do not add any value.
3) Unnecessary movements should be restricted to improve quality of work and workers productivity.
4) 5 S (Sort ,Simplify ,Sustain ,Standardize, Shine) are implemented in the work place5) With the help of workers types of waste such as transportation, reworking, waiting,unnecessary inventory, over processing are identified and using PDCA (Plan, Do, Check and Act) slowly eliminated.

4.7 Design Modification in the Head Stock and Tail Stock
4.7.1 Head Stock
Head stock is one of the pivotal part in the lathe machine (figure 2), which holds the rawmaterial. A design modification in the head stock reduces raw material set uptime, as in the present situation there is an alignment problem, it consumes a lot of time inaligning the raw material horizontally it needs to be hammered hence with the designmodification the problem can be eradicated.

Fig. 2: Head Stock of Lathe before and After Modification

In the proposed method an L-joint is added as a fixture i.e. it gives the raw material a rightangle (perpendicular) inclination which is required for the work to be carried out on workpiece (figure 2). Hence it saves a lot of time in hammering which is carried out presently,the added advantage is it also reduces raw material vibrations drastically which helps insmooth surface finish. Likewise design modification in the head stock improves theperformance and reduces the time and it also helps in improvement of productivity therebyprofits.

4.7.2 Tail Stock
Tail stock is one of the important parts in lathe machine which holds the tool bit. A designmodification in the tail stock reduces the time for movement of tool as the movementbecomes faster and easier which in turn reduces the lead time. The fast movement of tool bitcauses the reduction of time.

Fig. 3: Tail Stock of the Lathe before and after Modification

In the proposed method conventional rotating wheel is replaced with gears (gear trains)mechanism which helps the drill bit to move fast by simple rotations as the horizontalmovement of drill bit will be faster comparably(figure.3). Hence with the proposed methodof design modification a lot of time can be saved which in turn increases productivity andprofits.

5 Results and Discussions

5.1Verification and Validation of design
Modification in head stock and tail stock by thorough analysis of design modification, thevariation in the process was minimized by using 5 S technique, design modification and Kanban led to minimized lead time and effective utilization of labour which in turn increasedprofit margin.
Validation of data was carried for one more important reason i.e., to minimize the underutilization of resources like men, material and machines so that company's goals areachieved and profit margins are increased in the long run.
In data collection stop watch was used to record the time taken for each operations, tenreadings were recorded so that average time can be taken and likewise at eachoperation data was collected. The manufacturing process of pivot pin was observed for amonth so that actual scheduling can be summarized likewise lead time datawas collected throughout the shop floor for manufacturing of a pivot pin which involvesoperations like milling, drilling, tapping, chamfering, turning from start to finish of theproduct.The operation time taken before and after for carrying out facing, drilling and chamfering operation PC-71, PC-30 and PC-210 to are represented in the figures 4 to figure 9.

Table 1: Summary for pivot pin operations

Operations	Time taken for various operations before and after design modification (in seconds)								
	PC-71			PC-130			PC-210		
	Before	After	Savings	Before	After	Savings	Before	After	Savings
Facing	840	600	240	1320	1080	240	1560	1200	360
Drilling	600	480	120	960	780	180	1140	960	180
Chamfering	240	180	60	300	240	60	300	240	60

5.2 VSM for PC-71, PC-210 and PC 130
The current and future state VSM was drawn to make comparative study and to identify the value added and non-value added time in the processes of pivot pins PC-71, PC-210 and PC 130.

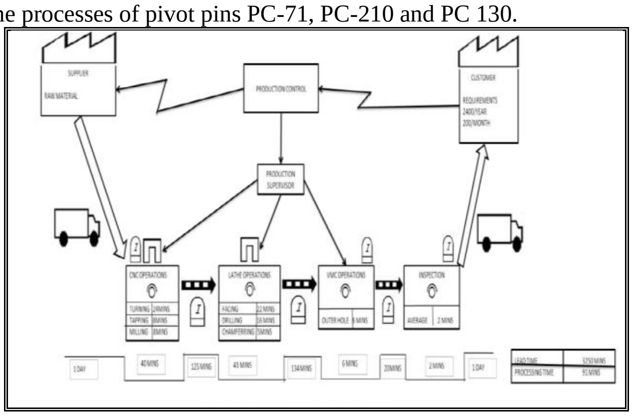

Fig 4: PC-130 Current State Map

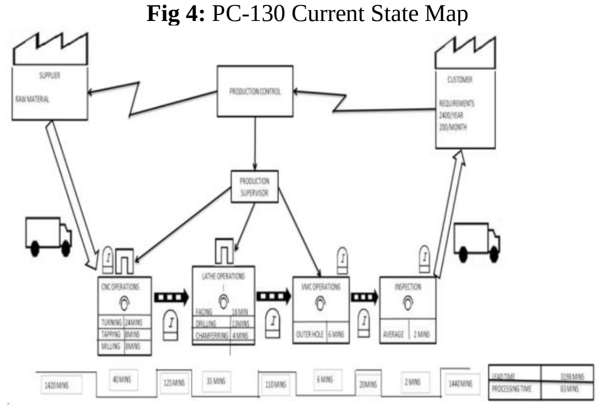

Fig.5: PC-130 Future State Map

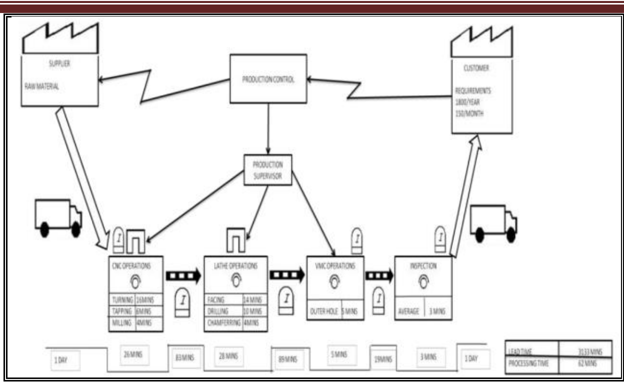

Fig.6: PC-71 Current State Map

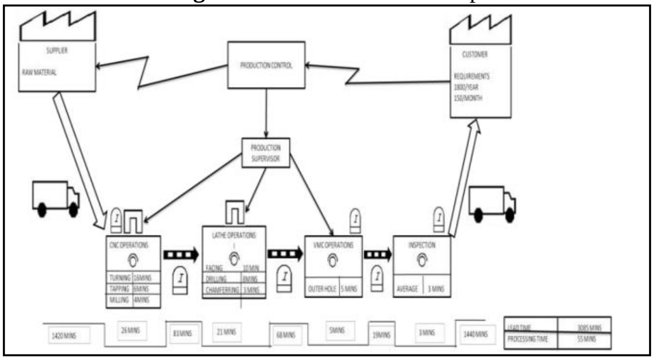

Fig. 7: PC-71 Future State Map

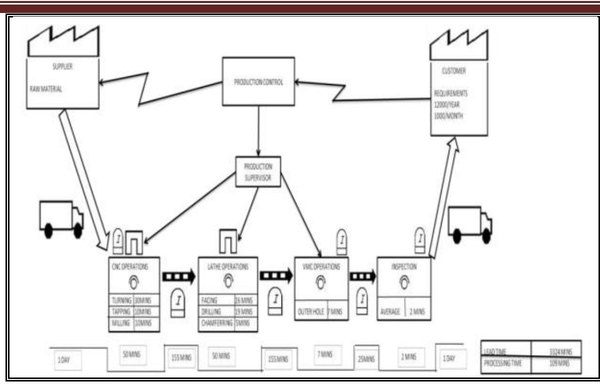

Fig.8: PC-210 Current State Map

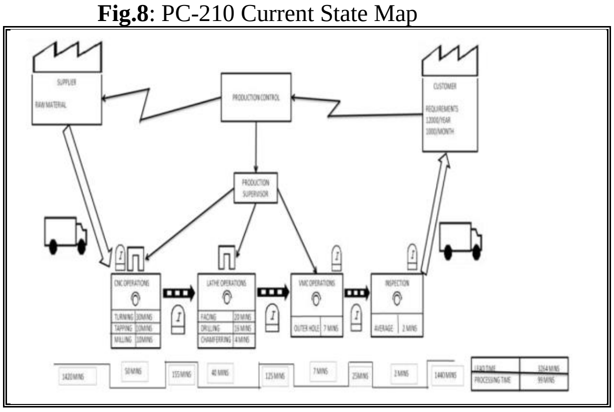

Fig. 9: PC-210 Future State Map

Table 2: Summary of Current State Map vs. Future State Map of Excavators

Parts	Current state map	Future state map
PC – 130	This current state map shows themanufacturing of pivot pins and theoperations involved in it. Here theraw material handling is poor whichtakes a day and the disposal of rawmaterial at each machine is not doneregularly, thus increasing the leadtime. Here the machine are outdatedand of poor quality. This map showsthe lead time of 3250 minutes andprocessing time of 91 minutes.	In future state map the raw materialis kept at each machine based on therequirement and fulfils the requirementfor the day's work which in turn savestime and helps in reduction of lead timeand increase productivity. Here designmodifications are made so as to facilitatethe improvement of the process. Hence,we can observe that lead time is decreaseto 3198 minutes and processing time isreduced to 83 minutes.
PC – 71	This current state map shows the manufacturing of pivot pins and the operations involved in it. Here the raw material handling is poor which takes a day and the disposal of raw material at each machine is not done regularly, thus increasing the lead time. Here the machine are outdated and of poor quality. This map shows the lead time of 3133 minutes and processing time of 62 minutes.	In future state map the raw material is kept at each machine based on the requirement and fulfils the requirement for the day's work which in turn saves time and helps in reduction of lead time and increase productivity. Here design modifications are made so as to facilitate the improvement of the process. Hence, we can observe that lead time is decrease to 3085 minutes and processing time is reduced to 55 minutes.
PC – 210	The current state map shows the manufacturing of pivot pins and the operations involved in it. Here the raw material handling is poor which takes a day and the disposal of raw material at each machine is not done regularly, thus increasing the lead time. Here the machine are outdated and of poor quality. This map shows the lead time of 3324 minutes and processing time of 109 minutes.	In future state map the raw material is kept at each machine based on the requirement and fulfils the requirement for the day's work which in turn saves time and helps in reduction of lead time and increase productivity. Here design modifications are made so as to facilitate the improvement of the process. Hence, we can observe that lead time is decrease to 3264 minutes and processing time is reduced to 99 minutes.

Table 3: PC-71 Processing Time for Current State Map and Future state map

Sl. No	Operations	Machine	Processing Time (Min)		Cost of Machine Per Hour (Rs.)	
			Current	**Future**	**Current**	**Future**
1	One side facing	Lathe	7	5	100	100
2	Second side Facing	Lathe	7	5	100	100
3	Drilling	Lathe	10	8	100	100
4	Chamfering	Lathe	4	3	100	100
5	Inspection		3	3	100	100
	Total		**31**	**24**		

Total time saved from PC-71, PC-130, PC-210 annually = 210+320+2000= 2530 hours.

Total cost saved from PC-71, PC-130, PC-210 annually =199920+32016+20988=252924/-

5.3 Processing Time and Cost Analysis for PC-71 Pivot Pin

Table 3 shows the average time taken to manufacture a pivot pin in current and future process for model PC-71.

Table4: Summary Table for a PC-71, PC 130 and PC 210 Pivot Pin

Components (Pivot Pin)	Parameters	PC-71	PC-130	PC-210
Current State	Time (Min)	62	91	109
	Cost (Rs)	51.66	75	86.66
Future State	Time (Min)	55	83	99
	Cost (Rs)	40	61.66	70
Savings	Time (Min)	7	8	10
	Cost (Rs)	11.66	13.34	16.66

6.Conclusions

The study aims at reducing the lead time of the manufacturing of pivot pin used inexcavator machines. By implementation of Value Stream Mapping and 7 QC tools, the rootcauses of the long lead time and processing time was identified. Further, design modificationscarried out which resulted in ease of working there by reduced lead time and non-value addedactivities.Hence with all above changes lead time has come down which increased the profitability,reduces manufacturing cost ,improved overall efficiency and delivery of products fast whichhelps in keeping good customer base.

In manufacturing of pivot pin for excavator machine model PC-71 by implementation ofValue Stream Mapping and 7QC tools we have saved 12600 min and a cost Rs 20988 formanufacturing 1800 pins.In manufacturing of pivot pin for excavator machine model PC-130 by implementation ofValue Stream Mapping and 7QC tools we have saved 19200 min and a cost Rs32016 formanufacturing 2400 pins.

In manufacturing of pivot pin for excavator machine model PC-71 by implementation ofValue Stream Mapping and 7QC tools we have saved 120000 min and a cost Rs199920 formanufacturing 12000 pins.The overall time saved is 2530 hours and cost of Rs252924 in manufacturing of pivot pins forexcavator machines models PC-71, PC-130, PC-210.

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