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Lead Time Reduction in Order Execution of Horizontal Slurry Pumps Using Lean Concepts for Mining Equipments Manufacturing Company

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Abstract—This paper addresses the lead time reduction in order execution of horizontal pumps using lean concepts for mining equipments manufacturing company. The mining equipments manufacturing company, which manufactures many varieties of products like Hydro cyclones, Slurry Isogate valves, Dewatering pumps, Horizontal slurry pumps, Vertical slurry pumps, rubber products, etc. Among these, the goal of this project is concern with lead time reduction in order execution of Horizontal slurry pumps, evaluating the results and implementing the same concepts to achieve lean to all products developed by the company. From the collection of past history sample of data, tracking the lead time for Horizontal pumps shows that, the lead time to manufacturing one pump (one complete order execution) is more than 90 days. This can be reduced by identifying the micro levels activities and separating each micro level of activities into value added or non-valued added activities and its time taken, after this eliminating some of the waste activities, adding improvement (kaizen) for the existing process or combining the activities for the same time in each micro level of activities throughout the order execution process, starting from customer placing a purchase order to product dispatched to the customer. The lean concepts like Kaizen's (continuous improvements), Heijunka (Japanese word- means leveled production), VSM (value stream mapping) to reduce the total lead time.

Index Terms— lead time, lean manufacturing, Value stream mapping (VSM), kaizen, Heijunka, Horizontal slurry pumps, Order execution.

1 INTRODUCTION

With manufacturing is becoming a more and more competitive market, companies globally strive to increase their efficiency. The increasing labor costs in many industrialized countries, as well as reducing and controlling operating costs, are just a few reasons companies choose to move or outsource their operations. Typically a majority of companies outsource to countries where wages are low and production costs are lower. To reduce cost and remain competitive with manufacturers, companies use a variety of different methods. One of the main methods is called "lean manufacturing" [1].

The main principle of lean manufacturing is to reduce waste in an operation, such as long lead times, defects and material waste. In order to visually display where waste occurs in the process, a value stream map (VSM) is drawn. Value stream mapping are often used to assess current manufacturing processes as well as create ideal, future state processes. With the manufacturing field escalating and spreading more widely across the globe, it is important for companies to adapt to the increasing and evolving business strategies [2].

It requires constant effort at cost reduction to maintain continuous profits in manufacturing. The prime way to reduce costs is to produce only those products determined by sales in a timely fashion, to restrain excessive manufacturing and to eliminate all waste in manufacturing methods. There are various ways to analyze and implement cost reduction, from the start of designing all the way through to manufacturing and sales. One of the goals of Lean Manufacturing is to locate waste pragmatically in each process and then eliminate it. It is possible to uncover a very large amount of waste by observing employees, equipment, materials and organization in the actual production line from the perspectives of the process itself and the actual work involved. Some types of waste are obvious, but others are hidden. Waste never improves value; it only increases cost. The elimination of waste leads to greater employee self-respect and to major cost reductions by preventing unneeded losses [3].

1.1 Lead time definition

"A lead time is the period of time between the initiation of any process of production and the completion of that process. Thus the lead time for ordering a new car from a manufacturer may be anywhere from 2 weeks to 6 months. In industry, lead time reduction is an important part of lean manufacturing." [7]

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1.2 Different types of lead times:

By definition the lead time is the time period between the initiation of any process of production and the completion of that process, in manufacturing sector the lead times are classified as fallows:

i. Lead Time in Supply Chain

Lead Time is the time between the initiation of a process and its completion. In Supply Chain Management there are 2 types of lead times:

- Information lead time
- Manufacturing Lead Time

Information lead time refers to the time span between information flows for a process from starting of the activities to end of the activities. **Manufacturing lead time** refers to the time span from material availability at the first processing operation to completion at the last operation.

ii. Make Items lead time

As shown above, there are 4 different types of lead times required to make an item or an item lot.

- **Pre-processing Lead Time**: The time required to create a work order (discrete job) from the time you learn of the requirement. It is also known as "planning time" or simply "paperwork".
- **Processing Lead Time**: The time required to make/ manufacture the item.
- **Fixed lead time**: The fixed lead time is a portion of processing lead time which is **not dependent** of order quantity
- **Variable lead time**: Portion of processing lead time which is **dependent** of order quantity.

The total lead time is equal to the fixed lead time plus the variable lead time multiplied by the order quantity. The planning process uses the total lead time to calculate order start dates from order due dates.

iii. Buy items lead times

Understanding buy items lead times is simpler.

- **Pre-processing Lead Time**: The time required to create a Purchase Order from the time you learn of the requirement. As for Make items, the buy item pre-processing lead time is also known as "planning time" or simply "paperwork".
- **Processing Lead Time**: The time required to buy an item.
- **Post processing lead time**: The time required to receive a buy or transfer item from the receiving dock to inventory (it includes quarantine, inspection time, etc.)

iv. Cumulative lead times

Please find below ***Figure 1.1*** showing an illustration of the different cumulative lead times that are found in manufacturing processes.

- The **Cumulative Manufacturing Lead Time** is the time required to manufacture an item if you had all raw materials or components in stock but had to make all subassemblies level by level.
- The **Cumulative Total Lead Time** is the time required to manufacture an assembly or an item if you had to order all raw materials or components and if you had to make all subassemblies. [13]

1.3 Lead time in Order Execution

In this paper the lead time in order execution of pumps is the total time taken to manufacture a pump, i.e., the total time taken starting from customer placing an order for manufacturing a pump to until customer receives the order (finished pump).

2. LITERATURE REVIEW

Some of the recent research works available in the literature are described in this section. Fawaz Abdullah et al., [1] has described about the Most Important Factor in Achieving World-Class operations In the 1960s and 70s, manufacturers competed on the basis of cost efficiency. In the 1980s, quality was the rage and Zero Defects and Six Sigma came into vogue. Cost and quality are still crucial to world-class operations, but today, the focus is squarely on speed. Nearly all manufacturers today are under pressure from customers to cut lead times. And rapid-response manufacturing pays big dividends.

Brito, M. P., & van der Laan, E. A et al [3] has described that, in many manufacturing plants, less than 10% of the total manufacturing lead time is spent actually manufacturing the product. And less than 5% of total customer lead time is spent in the production process. The cumulative cycle times of the processes in the value stream are the theoretical limit to how much we can reduce lead times, without investing in different equipment. Clearly, there is ample opportunity to reduce lead times in most organizations. Reducing lead times doesn't involve speeding up equipment to cut the cycle times or getting plant personnel to work faster. What is does involve is the *rapid fulfillment of customer orders* and the *rapid transformation of raw materials into quality products in the shortest amount of time possible.* The sample lead time analysis for a product line at a plant is as shown in ***Table below.***

MAIN ACTIVITY	TOTAL DAYS	%
Processing	3.0	7.5
In-transit	0.5	1.3
Set-up/ changeover	0.5	1.3
In queue	30.0	75.0
On hold-waiting for materials	4.0	10.0
On hold-quality	2.0	5.0
Total	**40.0**	**100**

In the company, actual production accounted for only 7.5% of the total manufacturing lead time. As in most plants, the largest contributor to lead time is queue time - the time product is sitting idle waiting to be processed at the next operation. Waiting in inventory, tying up cash, adding no value and causing unnecessary customer waiting.

Hines P., Rich N, et al.[2] has described that, According to the TPS, **there are seven original wastes known as "muda,"** which means "waste" in Japanese. In order to create a lean working environment, these wastes need to be identified and depleted. The ***first muda*** is overproduction, which is producing more than necessary, or more than is needed by the costumer. The ***second muda*** is the presence of defects. Defects in products lead to more costs and waste of production time, as well as the effort involved in inspecting and fixing defects. The ***third waste*** is inventory. Inventory could lead to added storage costs as well as higher defect rates. Even if there is no "inventory fee," large inventories cost company money because it increases their operating costs. The ***fourth muda*** is transportation, which could be transporting goods from one factory to another. Transportation, strictly seen, is a non-value added activity, so companies strive to lower transportation distances. The ***fifth muda***, waiting, is very important to lean manufacturing because this is one of the main wastes that production companies want to minimize. Waiting causes waste of time and money. The sixth waste is over processing. Over processing is unintentionally doing more processing work than the customer requires, which can lead to higher costs by using more resources than needed. The ***final waste*** is unnecessary motion. Walking from operation to operation or around the factory floor when not necessary slows down the workers and overall slows down the flow of production (Mekong, 2004). Detecting and diminishing these wastes within the production process will overall help to create a lean working environment within a company.

Guo-qiang Pan, et al. [4] presented about Value stream mapping, a lean manufacturing tool, which originated from the TPS, is known as "material and information flow mapping." This mapping tool uses the techniques of lean manufacturing to analyze and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, as

Hines, P., Holwe, M. & Rich, N. 2004 et al, [5] has described about Lean principles to become Lean requires a specific way of thinking, philosophy and management system which for Toyota is following "4P" model of the Toyota way. Liker (2004) describes in his book "The Toyota Way" fourteen principles which present the foundation of getting Lean at Toyota Production System (TPS). The author divides these principles into four categories all starting with the letter "**P**" – ***P****hilosophy,* ***P****rocess,* ***P****eople and partners and* ***P****roblem Solving*. This becomes known as so called "4 P" model of Toyota.

Czabke, J., Hansen, E.N. & Doolen, T.L, et al. [6] has described about Lean Manufacturing has increasingly been applied by leading manufacturing companies throughout the world. It has proven to have many positive outcomes which include such concepts as reduced cycle time, decreased cost, reduction of defects and waste. Lean manufacturing aims to achieve the same output with less input; such as less time, less space, less human effort, less machinery, less material and less cost. To better understand lean manufacturing, one first needs to understand the basic principles that guide it. Some major lean manufacturing principles include: recognizing wastes, having standard processes, having a continuous flow, pull-production, quality at the source and maintaining continuous improvement

3. PROPOSED APPROACH FOR LEAD TIME REDUCTION IN ORDER EXECUTION.

In the proposed approach to reduce the lead time in order execution process is briefly explained below.

- First step of the project is to understand the inter-customer chain relationship in between the entire department, i.e., studying about the roles, responsibilities and activities of all departments starting from customer ordering to order receiving in the manufacturing system.
- Then tracking the lead time from 3 months past history data for all work orders which is already executed for Horizontal slurry pumps, analyzing them calculating the approximate average lead time.
- The complete order execution process is sub divided into following main 4 stages by department wise, i.e.,

***Marketing to Engineering*:** Customer placing the purchase order for manufacturing pump after final conformations from accepting the engineering drawing and Bill of materials released for specific pump, which is given to the supply chain management to precede further action.

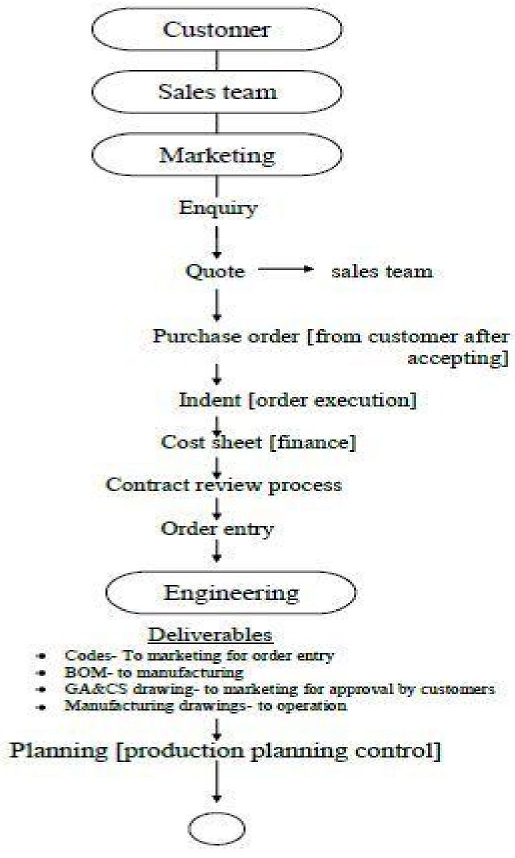
***Engineering to SCM*:** The confirmed BOM and Drawings from engineering department to Supply chain management activities, this includes procurement process of raw material for the assembly of pump, the important materials like castings- impellers, casings, expellers, etc, which is more cost and its can't be able to maintain Kanban system, so ordering these costlier and long lead time imported raw material from suppliers (pull system). This is followed until all materials get procured.

Procured Materials to Assembly and Testing: Once casting materials procured, it has to be machined i.e., drilling holes, boring, surface machining, etc. This machining process will do in our company shop floor (in-house machining) as well as outsourcing. Later as per the planning the Assembly and performance testing is done.

Testing to Dispatch: This includes final inspection, painting, customer dispatch clearance and dispatch to the customer.

- In these above main 4 stages discussed, listing out all the micro level of activities in ***Activity flow chart*** and ***process flow chart*** is made. Identifying the problems, bottle neck process, value added activities, non-value added activities and its time duration, the ***Value stream mapping*** is made for the Current state.
- Eliminating the waste activities and improvement (kaizen) are made to reduce the total lead time and preparing ***activities flow chart, process flow chart and Value stream mapping*** for the Future state.
- Next, implementing these step by step processes as per the future state activities chart and VSM and checking the total lead time.
- Further reduced lead time will becomes the current state lead time and same procedure is made for future improvements to reduce lead time as much as possible.

The **order execution process** of manufacturing a pump in the company is the step by step following activities starting from customer placing an order to till the customer receiving the finished product and the sequence of steps are shown in ***Figure 1***



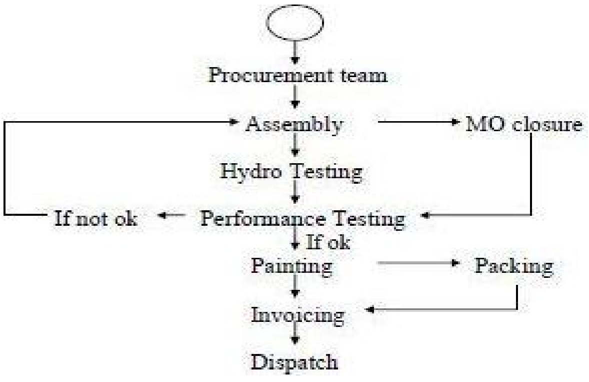


Figure 1: Order execution process.

4. ANALYSIS OF EXISTING LEAD TIME.

To understand the approximate existing value of lead time for horizontal pumps, the Past history of 3 months sample of data has been collected for the individual work orders. The complete order execution process is sub divided into mainly 4 stages for tracking lead time i.e.

1. Lead time between Customer Purchase Order Date and BOM/Drawing Release Date.
2. Lead time between BOM/Drawing Release Date and Last Material Procured Date.
3. Lead time between Last Material Procured Date and Assembly & Testing Date.
4. Lead time between Assembly & Testing Date and Invoice and Shipment Date.

By collecting the dates of above main 4 stages the lead time tracking is made for sample data of work orders for the months of November 2011, December 2011, and January 2012. The Sample of lead time tracking data is shown in ***Table 1 (next page).*** The graph for the lead time tracking of sample of work orders for the month of November 2011 is as shown in the ***Figure 2 (next page).*** By analyzing the lead time tracking data it is found that the lead time for one complete order execution of horizontal pump is 90-115 days which is very long lead time. The main aim of the project is to reduce the fluctuating lead time by less than half of present. This lead time can be achieved by identifying micro level of activities, eliminate the bottle neck operations, identifying the valued added activities, non valued added activities and slow down processes in complete order execution process and eliminating them or minimizing them by making continuous improvements (kaizen) or by combining the two or more activities for the same time. And further clear cut pictorial view of process flow chart, activities flow chart and Value Stream Mapping [VSM] is made.

Table 1: Sample of lead time tracking data

Sl no.	ORDER #	A= CUSTOMER EXPECTED DATE	B=INVOICE DATE & SHIPMENT DATE	C= B-A	1 CUSTOMER PURCHASE ORDER DATE	LEAD TIME B/W 1 & 2 DAYS	2 BOM/ DRAWING RELEASE DATE	LEAD TIME B/W 2 & 3 DAYS	3 LAST MATERIAL PROCURED DATE	LEAD TIME B/W 3 & 4 DAYS	4 ASSEMBLY & TESTING DATE	LEAD TIME B/W 4 & 5 DAYS	5 INVOICE AND SHIPMENT DATE	Total Lead Time= 5 -1 (DAYS)
1	WO-11/0663	30/11/2011	03/12/2011	3	12/07/2011	7	19/07/2011	111	07/11/2011	22	29/11/2011	4	03/12/2011	144
2	WO-11/1135	07/12/2011	09/12/2011	2	12/09/2011	9	21/09/2011	49	09/11/2011	16	25/11/2011	14	09/12/2011	88
3	WO-11/1324	08/12/2011	09/12/2011	1	10/08/2011	13	23/08/2011	75	06/11/2011	25	01/12/2011	8	09/12/2011	121
4	WO-11/1324	09/12/2011	09/12/2011	0	30/08/2011	15	14/09/2011	52	05/11/2011	24	29/11/2011	10	09/12/2011	101
5	WO-11/1415	10/12/2011	09/12/2011	-1	13/09/2011	6	19/09/2011	64	22/11/2011	13	05/12/2011	4	09/12/2011	87
6	WO-11/1159	11/12/2011	16/12/2011	5	14/09/2011	10	24/09/2011	59	22/11/2011	17	09/12/2011	7	16/12/2011	93
7	WO-11/1170	14/12/2011	16/12/2011	2	13/09/2011	6	19/09/2011	62	20/11/2011	17	07/12/2011	9	16/12/2011	94

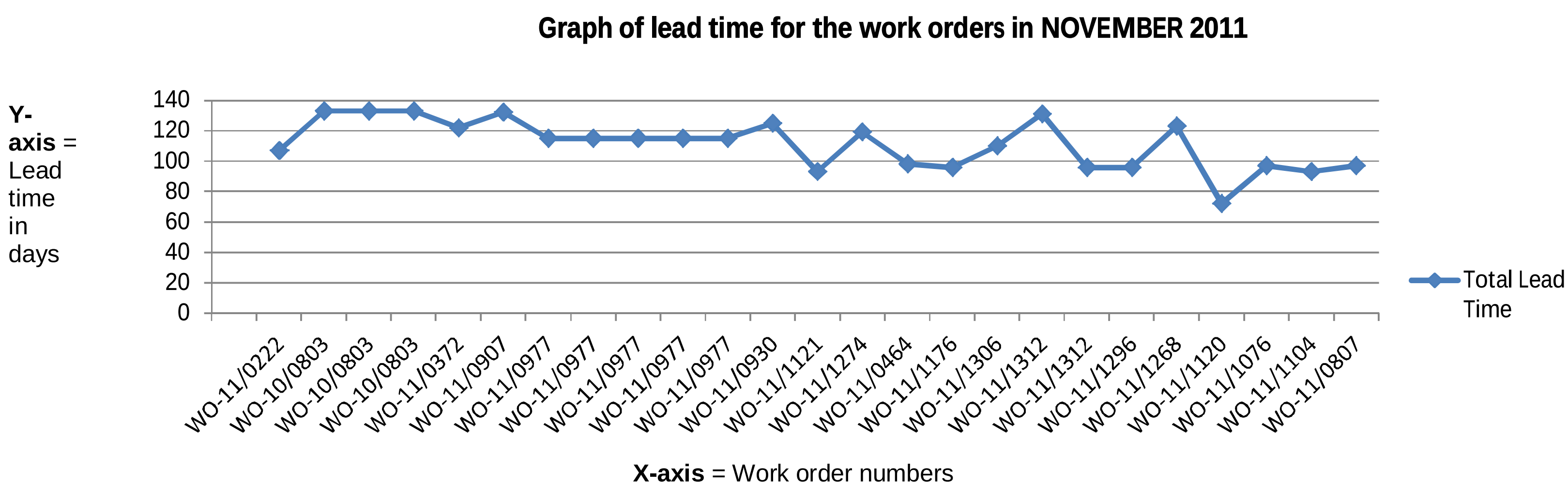


Figure 2: The lead time data from the sample of work orders in the month of November 2011.

5. CURRENT STATE VSM WITHOUT IMPLEMENTATION OF LEAN CONCEPTS

Initially, for any improvement, it is necessary to understand and analysis the existing/current state of the process, then efforts are made to create VSM for the current state without implementation of lean concepts. Value stream (= process) mapping (VSM) is a lean manufacturing tool, which originated from the TPS, is known as "material and information flow mapping." This mapping tool uses the techniques of lean manufacturing to analyze and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, as well as create flow in the manufacturing process. VSMs can be created merely using paper and pencil; however more advanced maps are created using Microsoft Visio as well as Microsoft Excel. The example of a very basic VSM created with Microsoft Visio is shown in below Figures.

The creation of a VSM is divided into five basic steps: 1) Identify the product. 2) Create a current VSM. 3) Evaluate the current map, identify problem areas. 4) Create a future state VSM. 5) Implement the final plan.

5.1 Steps to be followed for mapping VSM:

- To document all the steps in a process.
- To quantify the time of each step in a process.
- To map the current state value stream map.
- To identify the kaizen areas where value is added to a process.
- To draw future state value stream mapping
- To achieving the future state.
- Conclusion.

Before drawing VSM, start with Process Flow Chart and Activities Flow Chart.

5.11 The Process Flow Chart: Process Flow Chart describes the flow of step by steps of activities in micro level through out the complete process and also it represents the number of persons working for that activities, processing time, type of that activities followed by total time taking by that individual type of activities and Total processing time. All activities are classified into **5 types** which depends on whether it is

- Operations
- Transportation
- Inspection
- Delay
- Storage categories

The sample of current state process flow chart for the entire order execution process of horizontal slurry pumps is shown in the ***Table 2 (Page no.7). Followed*** by this, the next step is writing activities flow chart.

5.12 The activities flow chart: Activities Flow Chart describes the step by step of micro level of activities, with number persons working for those activities, processing time of individual activities and classifying the value added time and non value added time for those activities, fallowed by actions planned for reducing the total lead time or making improvements in that process. The sample data activities flow chart for the existing order execution process is as shown in the ***Table 3 (Next Page).***

After analyzing this, **The Existing State VSM or Current State VSM** for the horizontal pump is drawn as shown in ***Figure 3 (Next Pages).***

6. FUTURE STATE VSM AFTER IMPLEMENTATION OF LEAN CONCEPTS

6.1 Future state VSM: It is the modified drawing of the current state VSM, in the future state VSM evaluating the current state map and identifying the problems, eliminating the waste activities, adding continuous improvements to the current process (kaizen) and combining the two or more activities for the same output time to reduce the total lead time. Finally the **new process flow chart, activities chart and followed by updated Value Stream Mapping** is made which becomes Future state VSM. This process will be repeated to make ideal process, i.e., the future state becomes the current state and that will be re evaluated, adding improvements to it and modified to become once again existing state for the future.

After adding the improvements to current state, new process flow chart and activities charts are drawn, the sample of data of **Future State Process Chart, Activities Flow Chart,** is as shown in ***Tables 4, 5 (Next coming Pages).*** Followed by **new VSM for the future state order execution process** is made, which is shown in ***Figures 4 (Next coming Pages).***

To analysis the data after implementing the lean concepts once again the Lead time is tracked and the Sample of data collected from tracking lead time for the month of April/may 2012 after implementing lean concepts is as shown in ***Table 6 (Next coming Pages***). And its graph for the sample of data collection is as shown in ***Figures 5 (Next coming Pages)*.**

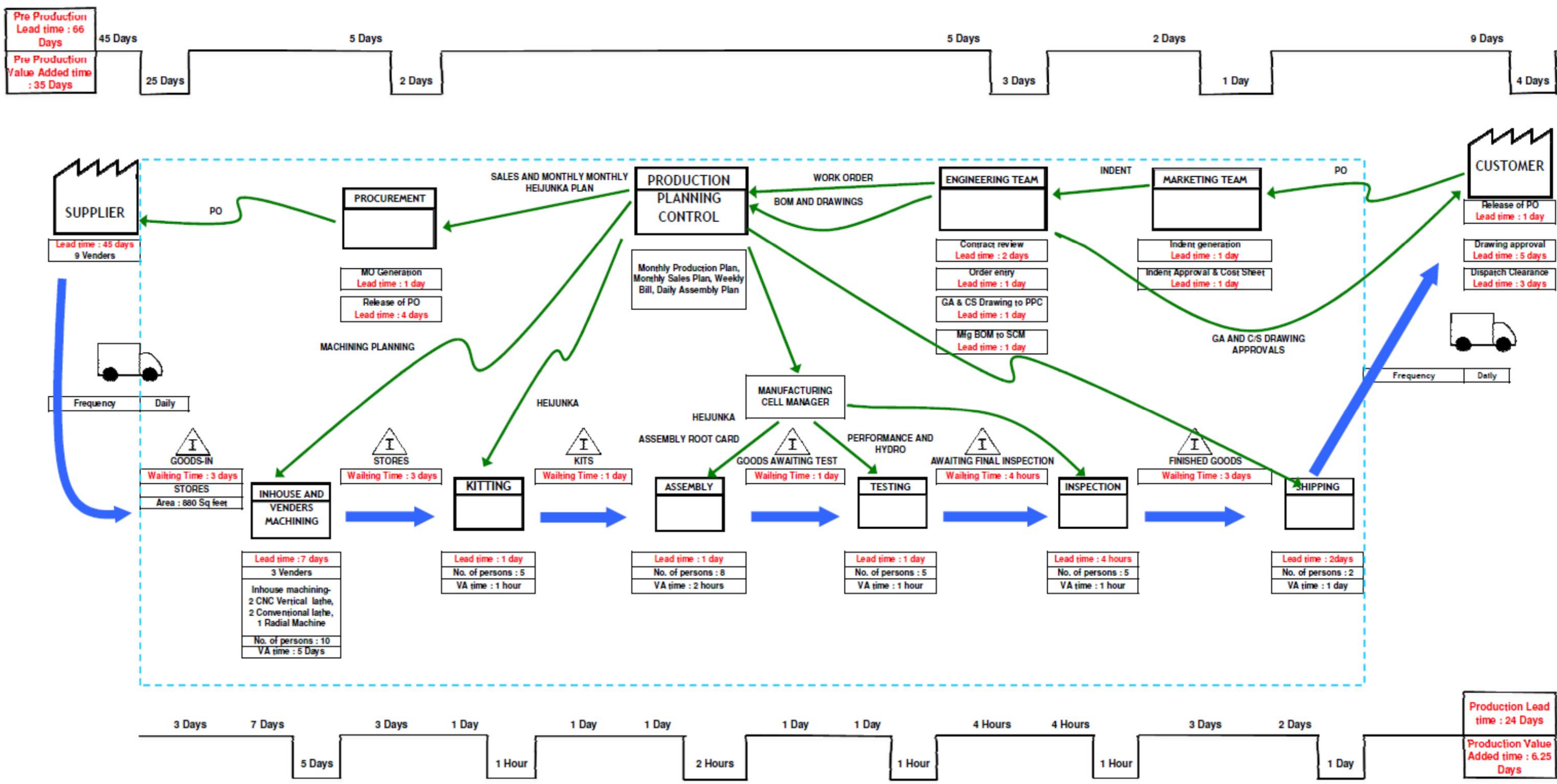
Table 2: The sample data of current state process flow chart for the entire order execution process of horizontal pumps.

PROCESS FLOW CHART FOR CURRENT STATE VALUE STREAM MAPPING OF 8/6 HORIZANTAL SLURRY PUMP				Operation	Transportation	Inspection	Delay	Storage
S.no	ACTIVITIES	Number of People	Processing Time (Min)					
	Steps between 1 to18 are Activities from Customer placing Purchase order (PO) to Engineering delivers ie, Drawing release and BOM release							
1	Receipt of PO for pumps, received from customer through Fax	-	1	○	⇨	□	D	▽
2	Submission of indent form in the employee portal, Team member-mktg gets an intimation automatically.	1	10	○	⇨	□	D	▽
3	Kick off meeting with all stakeholders (Engg, operations, finance, marketing) / Formation of Order Execution teams (Contract review??)	7	30	○	⇨	□	D	▽
4	Review of the order by team member marketing-HO	10	120	○	⇨	□	D	▽
5	Team member marketing prepares a project schedule All the stakeholders reviews the project details	5	480	○	⇨	□	D	▽

Table 3: The sample data of current state activities flow chart for the entire order execution process of horizontal pumps.

Sl #	ACTIVITIES	Number of People involved in Activity	Parrallel Processig Time(Min)	Processing Time (Min)	Value Added Activity Time (Min)	Non Value Added Activity Time (min)	Actions planned
	Steps between 1 to18 are Activities from Customer placing Purchase order (PO) to Engineering delivers ie, Drawing release and BOM release						-
1	Receipt of PO for pumps, received from customer through Fax	-		1	0	1	-
2	Submission of indent form in the employee portal, Team member-mktg gets an intimation automatically.	1		10	10	0	-
23	Release of receipt schedule for equipment parts by PPC-(Assembly plan.)	1		960	30	930	-
24	Issue of casting requirement by PPC	1	PP1=480		0	0	-
25	Planning of imports / bought-in by PUR	2		1920	30	1890	-
26	Follow up with purchase for the release of PO.	1	PP2=960				-
27	Release of PO for bought-in to vendors (for equipment) by PUR	4	PP3=60				-
28	Seeking Information for Accessories drawing and BOM from Engg according to sales plan.	1	PP4=480				Eleminating
29	Receipt of status of Accessories BOM.	-	PP5=480				Eleminating

CURRENT STATE VALUE STREAM MAPPING OF HORIZANTAL SLURRY PUMP



% OF VA = TOTAL VALUE ADDED TIME / TOTAL PROCESSING TIME*100=	42/90*100	46.67
% OF NVA = TOTAL NONVALUE ADDED TIME / TOTAL PROCESSING TIME*100=	48/90*100	53.33

Total ProcessingLead time	66+24	90 Days
Total Value Added time	35+6.25	42 Days
Total Non Value Added time	31+17.75	48 Days

Note : Considering the Total Working per day is 8 Hours, i.e., 1 Day = 8 hours

TOTAL NON VALUE ADDED TIME = TOTAL PROCESSING TIME - TOTAL VALUE ADDED TIME

VA: Value Added , PO : Purchase Order, GA : General arrangement, CS : Cross section, MO: Manufacturing order, BOM : Bill of materials, SCM : Supply chain management, PPC : Production planning control

Figure 3: The current state VSM for the horizontal pump.

Table 4: The sample data of future state process flow chart from the entire order execution process of horizontal pumps

PROCESS FLOW CHART FOR FUTURE STATE VALUE STREAM MAPPING OF 8/6 HORIZANTAL SLURRY PUMP								
Sl #	ACTIVITIES	Number of People	Processing Time (Min)	Operation	Transportation	Inspection	Delay	Storage
	Steps between 1 to18 are Activities from Customer placing Purchase order (PO) to Engineering delivers ie, Drawing release and BOM release	-						
1	Receipt of PO for pumps, received from customer through Fax	1	1	○	⇨	□	D	▽
2	Submission of indent form in the employee portal, Team member-mktg gets an intimation automatically.	7	10	○	⇨	□	D	▽
3	Kick off meeting with all stakeholders (Engg, operations, finance, marketing) / Formation of Order Execution teams (Contract review??)	10	30	○	⇨	□	D	▽
4	Review of the order by team member marketing-HO	5	120	○	⇨	□	D	▽
5	Team member marketing prepares a project schedule All the stakeholders reviews the project details	10	480	○	⇨	□	D	▽

Table 5: The sample data of future state activities flow chart for the entire order execution process of horizontal pumps.

Sl #	ACTIVITIES	Number of People involved in Activity	Processing Time (Min)	Value Added Activity Time (Min)	Non Value Added Activity Time (Min)	Problem	Kaizens
	Steps between 1 to18 are Activities from Customer placing Purchase order (PO) to Engineering delivers ie, Drawing release and BOM release						
1	Receipt of PO for pumps, received from customer through Fax	-	1	0	1	-	-
2	Submission of indent form in the employee portal, Team member-mktg gets an intimation automatically.	1	10	10	0	-	Updating on Employee Portal
3	Kick off meeting with all stakeholders (Engg, operations, finance, marketing) / Formation of Order Execution teams (Contract review??)	7	30	30	0	-	-
4	Review of the order by team member marketing-HO	10	120	30	90	-	-
5	Team member marketing prepares a project schedule All the stakeholders reviews the project details	5	480	240	240	-	-
6	Contract review meeting	10	30	30	0	-	-
7	Review of order details by the engg member	10	120	60	60	Review of order data was delay by each sub group members of engg and also queuing system for each	Updating on Employee Portal and Shared directory in data base for all departments .

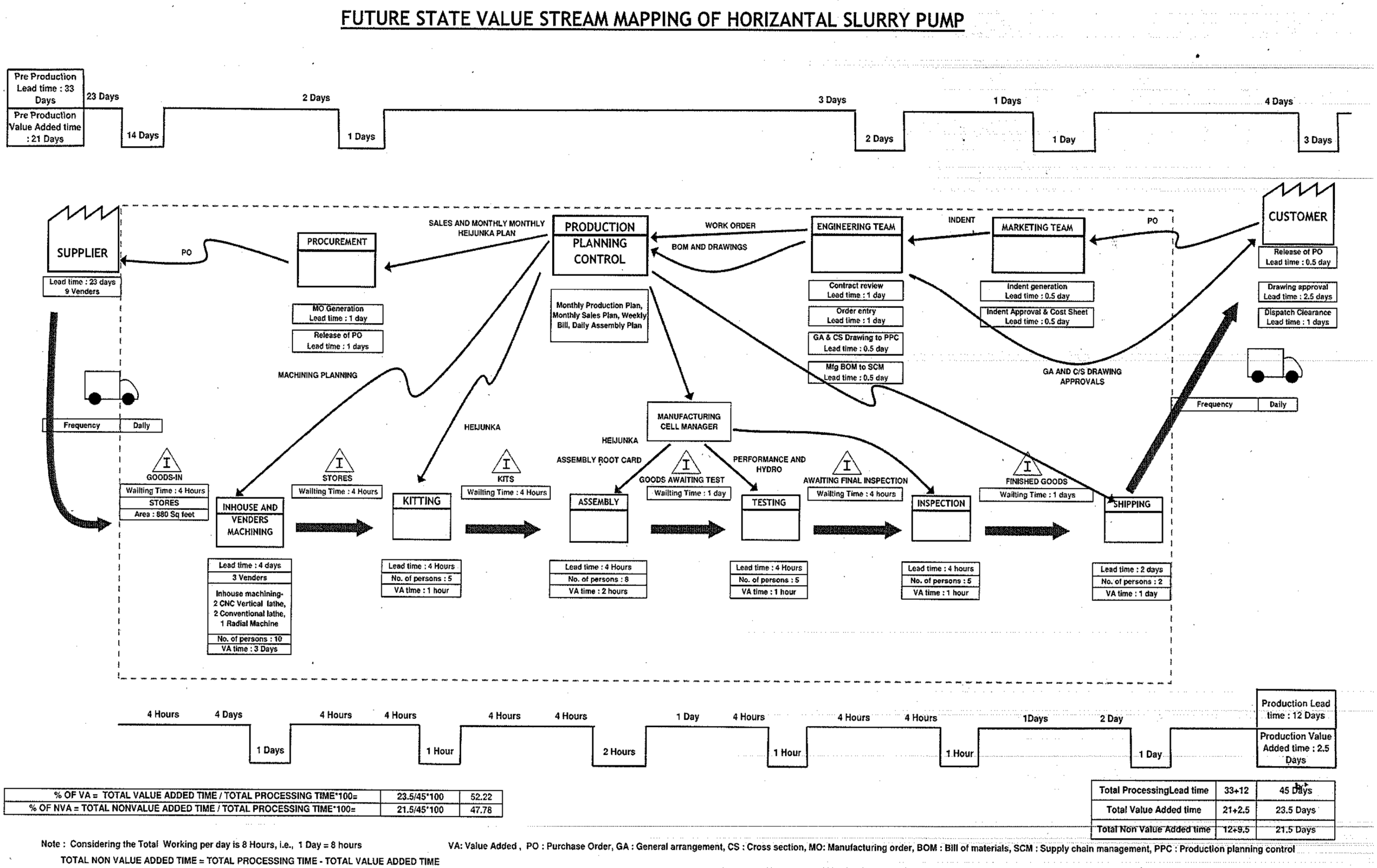


Figure 4: The future state VSM for the horizontal pump

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Table 6: Sample of data collected for tracking lead time of month April/may 2012 after implementing lean concepts.

Sl no.	ORDER #	A= CUSTOMER EXPECTED DATE	B=INVOICE DATE & SHIPMENT DATE	C = B-A	1 CUSTOMER PURCHASE ORDER DATE	LEAD TIME B/W 1 & 2	2 BOM/ DRAWING RELEASE DATE	LEAD TIME B/W 2 & 3	3 LAST MATERIAL PROCURED DATE	LEAD TIME B/W 3 & 4	4 ASSEMBLY & TESTING DATE	LEAD TIME B/W 4 & 5	5 INVOICE AND SHIPMENT DATE	TOTAL LEAD TIME = 5 -1
1	WO-12/0328	15/05/12	21/04/12	**-24**	05/03/12	8	13/03/12	28	10/04/12	7	17/04/12	4	21/04/12	**47**
2	WO-12/0329	13/05/12	24/04/12	**-19**	14/03/12	5	19/03/12	24	12/04/12	7	19/04/12	5	24/04/12	**41**
3	WO-12/0330	30/05/12	07/05/12	**-23**	21/03/12	7	28/03/12	27	24/04/12	8	02/05/12	5	07/05/12	**47**
4	WO-12/0331	30/04/12	15/04/12	**-15**	02/03/12	8	10/03/12	22	01/04/12	8	09/04/12	6	15/04/12	**44**
5	WO-12/0332	08/05/12	25/04/12	**-13**	14/03/12	8	22/03/12	21	12/04/12	8	20/04/12	5	25/04/12	**42**

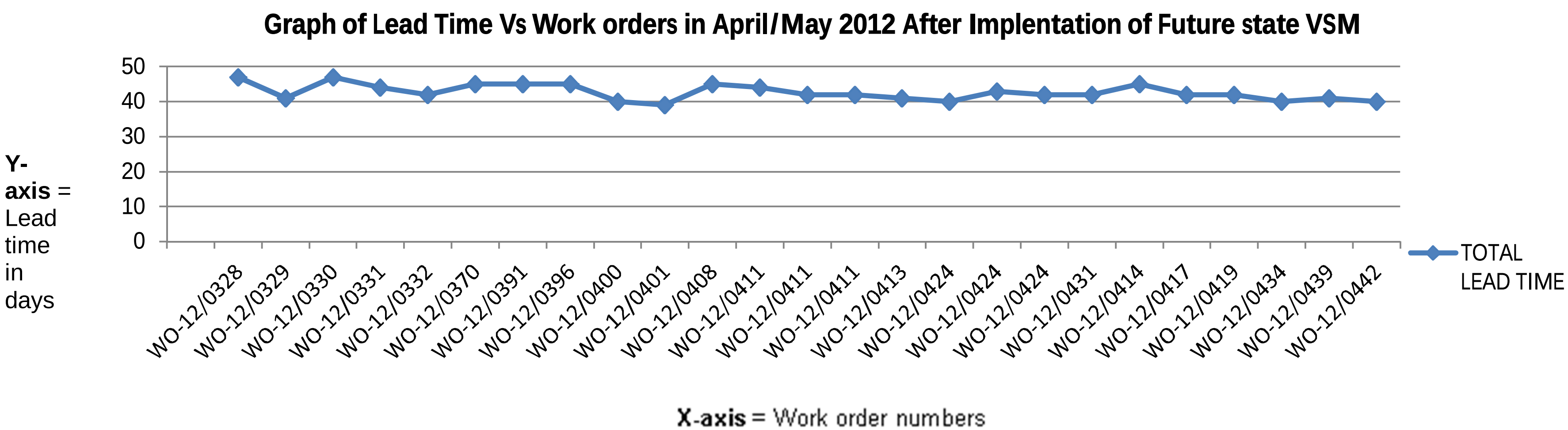

Figure 5: The lead time data from the sample of work orders in the month April/May 2012 after implementing lean concepts.

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Some of the Kaizen's added in this project with suitable formats are shown in below ***Figures 6 & 7***.

Kaizen Sheet

Productivity	Quality	Delivery	Safety	Material	Energy	Morale	MM/YY	Sl.No.
							01/12	12/01/ 03

Kaizen Theme : CycleTime reduction in Expellers

TEAM : Patil, Ramesh S, Bhuvaneshwara

Implemented Area: Machine Shop

Implemented By Prasanna, Aravind NS

Problem/Present Status:

Expeller like B028,C028,D028,E028,DAM028,EAM028. Cycle times are high

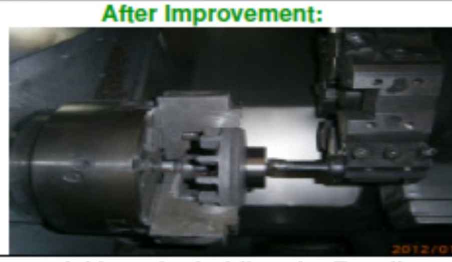
Before Improvement:

Target Setting :

Real Root Cause Identification:

Expellers cycle times are very high
Why
Machining in conventional Lathe
Why
There is no special jaws for holding the Expellers in CNC machine

After Improvement:



Result/Benefit:

1. Average cycle time reduced by 75% in Expellers
2. Machine shop OTD increased by 5%
3. Average cost saving in Expellers INR 10,000 Saved per month
4. Employee morale improved.

Standardization :

Root cause	There is no special jaws for holding the Expellers
Idea to eliminate root cause	Design & Implement the special Soft Jaws to CNC Machine
Countermeasure	To design special Soft Jaws

How many places this Kaizen can been deployed horizontally: All Expellers Dia below 300mm

Figure 6: kaizen for special jaws for holding the expeller.

Kaizen Sheet

Productivity	Quality	Delivery	Safety	Material	Energy	Morale	MM/YY	Sl.No.
							2/12	12/02/ 05

Kaizen Theme : Reducing painting time preparation

TEAM : Manjunath, Narasimhamurthy, Vasanth , Harish, Kodandaramappa

Implemented Area: Painting

Implemented By : Aravind.NS, Krishnappa.K

Problem/Present Status:

More preparation time taken for masking the pump shaft and lybrinth

Before Improvement:

Target Setting :

Real Root Cause Identification:

More preparation time taken for masking the pump shaft and lybrinth
WHY
Shaft and lybrinth masked with masking tape
WHY
No masking sleeve available for shaft

After Improvement:

Result/Benefit:

- Employee fatigue reduced
- Time reduced from 5 mins to 1mins per pump.
- No of activities reduced from 8 to 3
- 5S improved

Standardization :

Root cause	No masking sleeve available for shaft
Idea to eliminate root cause	To implement a masking sleeve for all sizes of shaft and lybrinth
Countermeasure	Fabricated masking sleeve according to sizes of the shaft and lybrinth

How many places this Kaizen can been deployed horizontally:

Figure 6: kaizen for masking before painting.

7. RESULTS AND DISCUSSION

7.1 Analyzation of the *Current State VSM* shows that,

- Pre-Production activities Lead time: **66Days.** In this, Pre-Production Value Added time: **35 Days** and
- Production process lead time: **24 Days.** In this Production Value Added time: **6.25 Days** i.e., Total processing time = Pre-Production lead time + Production lead time.i.e.,

Total Processing Lead time	66+24	**90 Days**
Total Value Added time	35+6.25	**42 Days**
Total Non Value Added time	31+17.75	**48 Days**

Percentage of VA (Value Added Time) for current state
= Total Value Added Time / Total Processing Time*100
=42/90*100 = **46.67%.**

Percentage of NVA (Non Value Added Time) for current state
= Total Non-Value Added Time / Total Processing Time*100
= 48/90*100 = **53.33%.**

Similarly after adding the improvements and eliminating the waste activities in future state the results obtained as follows.

7.2 Analyzation of *Future State VSM* shows that,

- Pre-Production activities Lead time: **33Days** in this, Pre Production Value Added time: **21 Days** and
- Production process lead time: **12 Days,** in this Production Value Added time: **2.5 Days** i.e., Total processing time = Pre-Production lead time + Production lead time. i.e.,

Total Processing Lead time	33+12	**45 Days**
Total Value Added time	21+2.5	**23.5 Days**
Total Non Value Added time	12+9.5	**21.5 Days**

Percentage of VA (Value Added Time) for future state
= Total Value Added Time / Total Processing Time*100
=23.5/45*100= **52.22%.**

Percentage OF NVA (Non-Value Added Time) for future state
= Total Non-Value Added Time / Total Processing Time*100
=21.5/45*100=**47.78%.**

7.3 Comparing the values from current state to future state reveals that,

i. The percentage of total lead time reduction is given by

= (A– B)/A*100
= (90-45) **/** 90*100 **= 50%**

Where**,** **A**=Total lead time of **Current State**,
B=Total lead time of **Future State.**

The graph shows decrease in lead time from current state to future state is as shown in the ***Figure 8***

ii. The percentage of increase in value-added time is given by,

= (A – B)/A*100
= (52.22-46.67)**/**52.22*100**=10.62%**

Where, **A**=% of VA time in **Future State**,
B=% of VA time in **Current State.**

The graph shows increase in value-added time from current state to future state is as shown in the ***Figure 9***

iii. The percentage of decrease in non-value-added time is given by,

= (A – B)/A*100
= (53.33-47.78)**/**53.33*100**=10.40 %**

Where, **A**=% of NVA time in **Current State,**
B=% of NVA time in **Future State.**

The graph shows decrease in non-value-added time from current state to future state is as shown in ***Figure 10.***

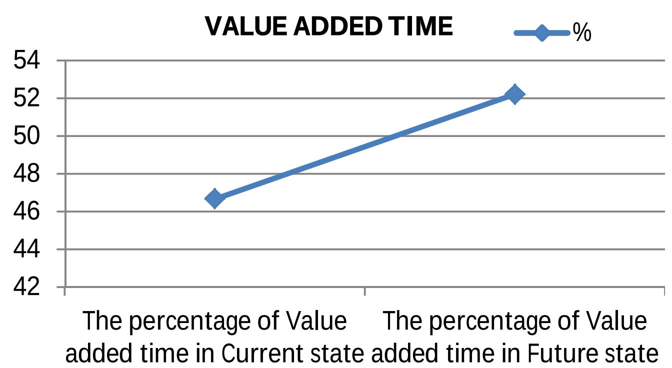


Figure 8: The graph shows decrease in lead time from current state to future state.

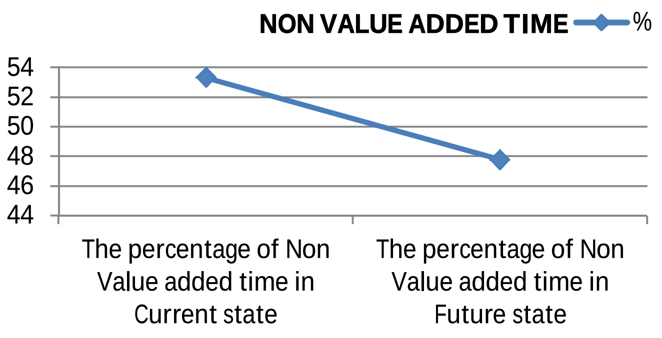


Figure 9: The graph shows % increase in value-added time from current state to future state

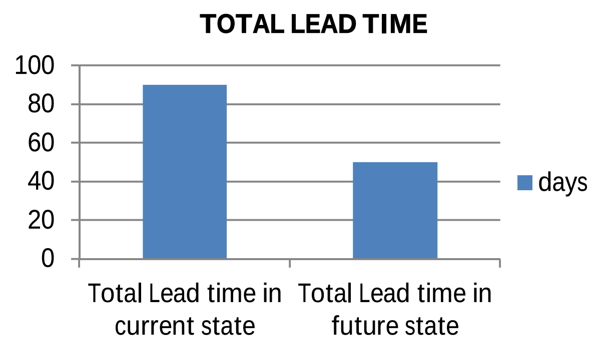


Figure 10: The graph shows % decrease in non-value-added time from current state to future state.

8. CONCLUSION

In the paper, Lean concepts has been successfully implemented in the manufacturing horizontal slurry pumps. Value stream mapping can be a valuable tool for developing and implementing warehousing lean improvement projects. By applying lean concepts, the lead time of horizontal slurry pumps is reduced up-to 50%.Now the future state VSM becomes current state VSM, in that still more new developments and improvements can be added to reduce lead time and achieve lean, this process is repeated until an ideal state is established. The process of creating the value stream map was helped and trained to all the warehouse team members on lean techniques and to reveal the opportunities on reducing waste. Lean concepts can also be implementing to other products in the manufacturing company, so that we can reduce the delivery lead time for all the products.

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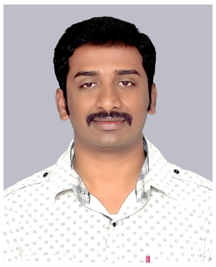

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