

# Lead Time reduction using Value Stream Mapping for a Mechanical Gear Manufacturing Firm

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**ABSTRACT:** In the manufacturing sector, the shop floor has numerous workstations. Each activity is interdependent and it is necessary to carryout specified tasks as per the schedule to meet production demands. A Value Stream Mapping (VSM) is a critical tool, which includes all activities required to transform raw material in to finished products. Shortage of inventory, unavailability of machine tools and breakdown of machine causes delay to meet production rate. Improper layout design, unidentified items and unnecessary flow of material creates fatigue to the operator. This eventually results in slower production rate. VSM analyzes the manufacturing processes from the beginning to the completion of tasks with the help of available facility, flow of material, people, products and information. A visual representation map can be drawn based on this. This map comprises of every single process involved in the material and information flow. Based on available data at present, future state map is drawn to show how things would work to attain a competitive advantage for a firm. Due to severe competition, firms are working at achieving minimal lead time, low cost and greater customer satisfaction.

**KEYWORDS:** VSM, value stream mapping, lean manufacturing, lead time,

## I. INTRODUCTION

Manufacturing organizations are forced to adopt new approaches for the improvement of production processes in order to produce better quality and cost effective products. Manufacturing units are consistently focusing on productivity as well as quality. In order to obtained high productivity along with quality, an organization must have efficient process flow in the firm. Overall manufacturing flow would be minimized and productivity can be increased, by merging the various process or operations where ever it's possible. Principles of lean manufacturing were developed from Japanese manufacturing industries. The term 'Lean', was invented by John Krafick (1988). Lean manufacturing has been considered a good start for manufacturing organizations as it focuses on improving production processes. Lean thinking not only helps in improving in enhancing productivity of the company but also high enough to improve the employee job satisfaction level. [1].21st century has forced universally, the leaders from the various manufacturing sectors to implement the competitive lean manufacturing systems [1].As per the researches the lean manufacturing system would be the standard manufacturing process for the 21st century. It would be a useful guideline to the world class organization in terms of cost reduction. The philosophy of lean manufacturing system is to provide a quality of products to the market or customers but does not much cost burdened [2]. The main aspect is to reduce the manufacturing cost of products considerably and make sure delivery of the same at the right time. This ability facilitates the organization to produce the quality product with a right price. This capability improves the competitiveness of the organization. An organization that needs to successfully compete in any market, mainly it will be focusing on its customer requirements. These requirements become company competitive priorities. Such as on-time – delivery, low cost, quality, innovation and flexibility etc. As per Japanese manufacturing system, customer is paying price to the good product not to defect. Different tools such as 5S, kaizen, Poke-yoke, Kanban, JIT etc. have been used while implementing lean manufacturing methods in any type of organization. In recent days, industry experts and researchers have initiated that the value stream mapping (VSM) technique is also as a powerful tool along with these tools in lean techniques to implement in an organization. Lean concepts focus on the elimination of hidden wastes involved in the product and process flows and achieve its goals. Today, lean manufacturing system has a great scope in manufacturing industries. Lean tools and principles have been widely used all over the world. Value Stream Mapping (VSM) is a vital tool in the Lean system. Toyota Motor Corporation in Japan developed VSM tool during 1980s. Value stream mapping is a lean technique which gives a visual representation of a workplace to show the flow of inventory and information required to produce a specific Product or service, from supplier to the customer. It gives visuals about

information flow, product flow and product timeline. Through symbols a process flow is shown on the chart. Value Stream Mapping is a systematic procedure used to document, analyze and improve the movement of materials and information required to produce a product or deliver a service to the customer. VSM is used to identify the current process of the organization in a detailed manner and helps to identify waste. The current state map is used to identify the wastes and non-value added activities in the production process. Some examples of value added activities are including assembly, molding, welding, painting etc. And Non-value added activities include walking, waiting, inspecting, cleaning, reworking etc. Value stream mapping is the only lean tool suggested to eliminate Muda, bottlenecks throughout the production line. Toyota's view was focused on the reduction of main three types of waste which are Muda (non- value-adding work), Muri (overburden) and Mura (unevenness) [3]. Nowadays companies are concentrated on continually to increase productivity and output of their operations. In recent years, the application of VSM has been expanded to many industry sectors due to ease of adoption like logistics applications, software development companies, for office activities, healthcare centers and other service-related industries.

#### BACKGROUND OF VSM

The Lean Manufacturing concept was practiced by Toyota for the first time in the 20th century through the development of a Lean Production System. Several approaches such as Total Quality Management (TQM), Total Productive Maintenance (TPM) and Just-in-Time (JIT) were initially introduced within the lean production domain. Later, it was discovered that Value Stream Mapping (VSM), when integrated with other TQM. Tools (5S, Kaizen etc.), can develop a sustainable production environment for almost every type of organizations [4].

#### OVERVIEW OF LEAN MANUFACTURING AND ITS TOOLS

After World War II Japanese manufacturers were faced with vast shortages of material, financial, and human resources. These conditions resulted in the birth of the "lean" manufacturing concept [5]. Kiichiro Toyoda, the president of Toyota Motor Company at the time, recognized that American automakers of that era were out-producing their Japanese counterparts by a factor of about ten. Early Japanese industrial leaders such as Toyoda, Shigeo Shingo, and Taiichi Ohno responded by devising a new, disciplined, process-oriented system, which is known today as the "Toyota Production System," or "Lean Manufacturing. The system focused on pinpointing the major sources of waste, and then using tools such as JIT, production smoothing, setup reduction and others to eliminate the waste. The 5S development has several other merits too. For example, it cultivates good human relationships in an industry or a firm and raises morale. A company, whose plants are clean and neat, will win the credibility of customers, suppliers, visitors and aspirants. Manufacturing sectors or any other kind of industries everywhere faces different challenges in day today activities. Due to globalization concept, competitiveness increased all over the world. There is a huge change in market demands, cost competition, manufacturing methods and flexibility, faster response to customers. In this modest world, market or customers are the one who determine the cost of product. Companies or organizations not only concentrating on reducing the costs which is influencing directly on the product along with that several hidden costs are present in the process. All manufacturing industries ought to focus on these hidden costs to removing it from the process. Hidden costs examples poor quality or defects, downtime, low efficiency, scrap rate, assigning overtime etc. Toyota implemented continuous improvements tools to avoid or to reduce these costs in the operations. CI tools are 5S, VSM, Kanban, Poka-yoke, OEE ,JIT etc.. The 5S pillars provide a methodology for organizing, cleaning, developing and sustaining a productive work environment. 5S are as follows [6]

- Sort ( Seiri)
- Set in order (Seiton)
- Shine(Seiso)
- Standardize (Seiketsu)
- Sustain (Shitsuke)

Each lean tool has its own methodology and benefits for each different sector. They are

- Reduction in lead times for end users
- Enhanced management knowledge
- Lowered inventories for manufacturer



Figure 1.1: The Benefits of ‘Lean’ [7]

OVERVIEW OF VSM

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).

There are four steps used in the Value Stream Mapping Cycle. They are as follows:

1. Create a Current State Map
2. Identify and Eliminate Waste
3. Create a Future State Map
4. Implement the Future State Map

Fig 1.2 illustrates the sequence of VSM activities in the form of flowchart

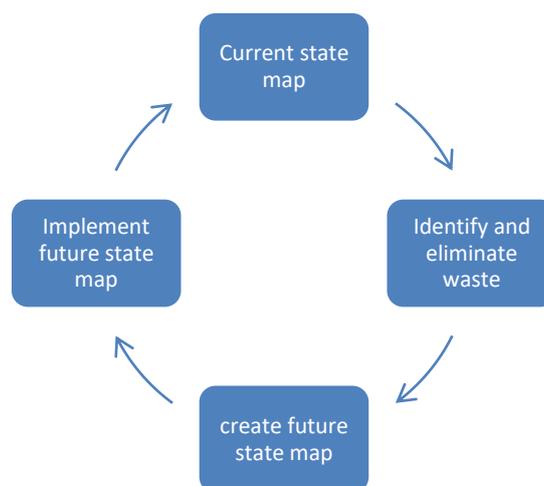


Fig 1.2 Value Stream Mapping (VSM) Flowchart [8]

SYMBOLS USED IN VSM

VSM SYMBOLS SHOWN BELOW IN FIG 1.3

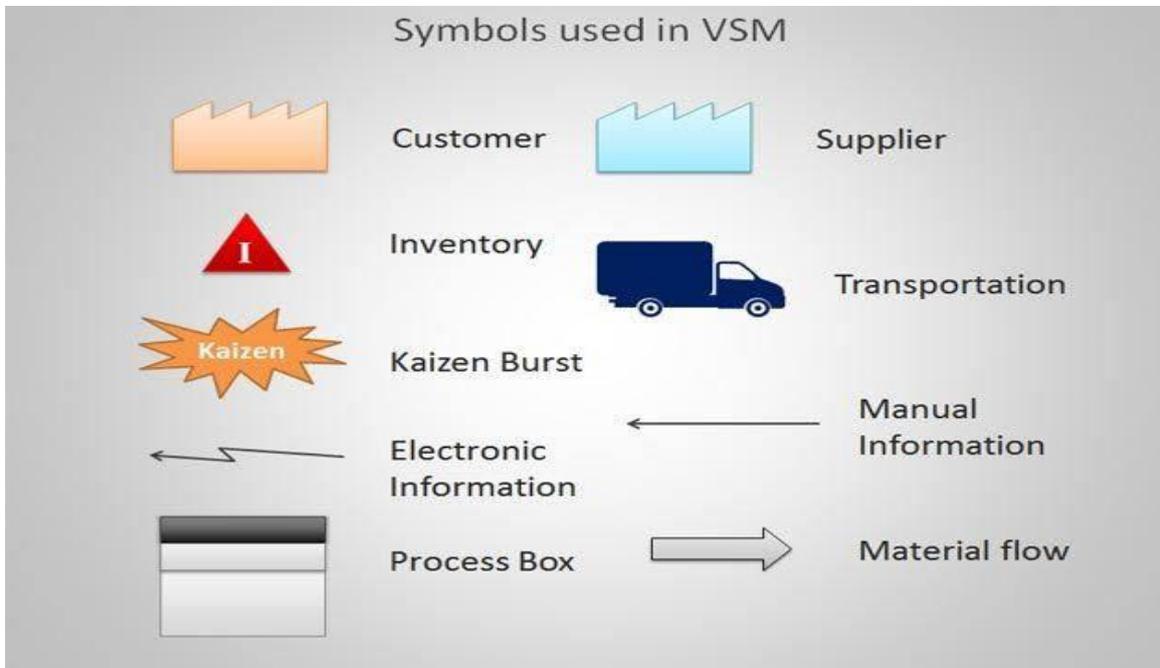


Fig 1.3 VSM Symbols [9]

TAKT TIME

This method illustrates the approach of identifying the manufacturing cycle time for all operations. The term Takt means beat. In simple, this is available time upon unit demand in a particular production period. This method identifies the amount of time required to complete a job, process, flow, transfer and ensures accomplishing targets [10].

Advantages of Takt Time

- Prevents over processing waste
- Allows precise scheduling
- Allows synchronized production process
- Ensures steady production rate
- Delivers spontaneous performance feedback

II. LITERATURE REVIEW

INTRODUCTION

This section covers the literature review, studies and related opinions given by various researchers relating to waste identifications and improvements methodology. The literature topics were selected based on the present work in order to have a brief idea of the tools and techniques previously discussed and applied in their paper or journals and the obtained feasible results.

Mastan Singh<sup>1</sup> et al. [11] This paper address a case study of Fastener Industry. This case study identifies the existing hidden different types of potential wastes. Its ultimate goal is to eliminate waste and non-value added activities in the process in order to achieve the customer satisfaction. Hence, Productivity improvements by using the VSM methods. After the implementation of VSM, the industry achieved enormous benefits are Production lead time reduced from 35.55 days to 16.85 days, processing time reduced from 309 seconds to 280 seconds and work- in - process inventory reduced. All these suggested changes led to a significant cost reduction of the company. Shubham A. Kadam<sup>1</sup> et al. [12]. In this production process case study, the author illustrates about the VSM techniques and discusses the application of Lean Practice initialization. As VSM involves in all of the process steps, both value added and non-value added are analyzed. Wastes like Muda (non-value-adding work), Muri (overburden) and Mura (unevenness) were

discussed. The wastages were identified in the current system are high additional processing time, consumes more resources, more inventory, high cycle time and more scrap. By implementing the value stream mapping the results obtained are Lead time of gear reduced from 32 days 7 hrs. to 17 days 3 hrs. The inventory period of the product reduced & the machining process made in continuous flow. Other Advantages Company could have benefited are. Continuous flow of materials, reduction in lead time, reduced in process inventory, reduced stock levels and cost. Sadaf Zahoor et.al. [13] The authors studied the efficient use of VSM to improve productivity by reducing process cycle time and waste in a gear manufacturing process in an automotive industry. To draw a current value stream map, the workplace is to be examined several times to get the flawless data. The collected data has to consist of: Process cycle time, Value added time, Non value added time Changeover time. Wastes identified are, excessive inventory, large processing time, mismanagement of resources, flaws in system layout. Authors concluded that after implementation of VSM integrated with Kaizen, reduced the lead time of the product and hence productivity. Later layout modified to a new layout, work flow resulting drastic reduction in total distance travelled by the product i.e. from 558ft to 120ft and also reducing the cycle time, reduction in process cycle time, reduction in inventory and reduction in total time for travel was achieved. The reduction in production lead time was significantly achieved to 67 %; initially it was 36%. Authors suggested that the VSM is a tool of “Lean Manufacturing” can be used for continuous process improvement. Rahani AR et.al. [14] In this process industry case study, the authors addressed the issues of wastes and how VSM can be utilized for identifying sources of wastes and eliminating waste, maintain better inventory control, improve product quality, and better operational control. Authors emphasized that the team has to collect data and information by walking in to the Gemba (Shop floor) and interviewing the concerned operator for the individual task. By interviewing the operators, technicians and an assembler, can provide the information about how tasks are performed. Following PDCA cycle for continuous improvement. After studying and implementation of VSM, Authors concluded that, considerable lower rejection rates in process, large gaps between standardized work and real work. Workers did not follow strictly assembly standards. In production shop floor, the operators are the key elements, they should be aware of the production process. Employee empowerment, involvement and continuous improvement play a major role in sustainability and long-term commitment to practice Lean in an industry. Adwait Deshkar et.al. [15] The authors studied the effective use of VSM method to improve productivity in plastic bag manufacturing unit. An attempt has been made in this paper to reduce production lead time using principles of Value Stream Mapping (VSM). The identified wastes were idleness, underproduction, unwanted WIP, high TAKT times, lack of pull and proper scheduling. VSM tools were utilized to eliminate non value adding activities, thus resulted in Percentage of value added time in the total lead time increased from 15% to 89.85%. TAKT time was reduced from 46.6 min to 26 min. Number of rolls made increased to 50 per day. The cycle time of pacemaker process was reduced thus increasing pace of overall process. Scheduling of work orders was also implemented to meet strict demand requirements and reduce load on machines and workers. Vaibhav S. kengar1 et al, [16] this paper describes the basic overview of manufacturing system performance improvements by using VSM. In this paper Authors are insisted that, it is possible to reduce lead time by reducing waste through proper scheduling, better team work, planning, training the workers and awareness in the workforce regarding the global competition. So VSM is applicable to any kind of industry for performance improvement. Authors introduced the following terminologies to study and draw current state map of VSM. Significance of Value Stream Mapping, Procedure for Mapping a Value Stream, VSM Symbols. The Seven Value Stream Mapping Tools

1. Process activity Mapping (OEE)
2. Supply chain response Matrix (Logistics)
3. Production Variety Family (OM)
4. Quality Filter Mapping
5. Demand Amplification Mapping
6. Decision Point Analysis (Efficient consumer response)
7. Physical Structure volume and value.

e.VSM Measures: Ex: Talk time, Lead time, Production Delivery Ratio, OEE, Rework rate, Defect rate, Scrap rate, Inventory, on time Delivery etc. Authors concluded that Value Stream Mapping (VSM) is a World Class Manufacturing tool that can be used to minimize waste in manufacturing. Case study under observation in this paper, so results are not concluded. Praveen Saraswat1 et al, [17] in this study, the author present the practical application of Value Stream Mapping (VSM) tool in bearing manufacturing industry for reduction in the WIP and Production Lead Time. During the observation Authors found that, the two processes Annealing and CNC Machining have higher cycle time and WIP. Author stated that before starting data collection and draw current state of VSM, the researcher must focus on classify the product group or families according to the problems. Authors concluded that by doing drilling and threading operation on the ground floor nearer to the CNC machining, the unnecessary movement of man and material was reduced. There by, total processing time was reduced from 409 seconds to 344 seconds. The reduction in

production in total processing time was significantly achieved to 15.9 %. Authors shown that the value stream mapping is an ideal tool to expose the waste in a value stream and to identify tools for improvement. P.M. Masuti 1 et al, [18] This paper address the elimination of MUDA (wastes) and bottlenecks across the production line in the Fabrication by using VSM tool. Authors found higher setup time at welding station of center section due to improper clamping of center section. Excess inventory at foot boss center station catches rust and requires regrinds, underutilized press station due to no provision of fixture are the problems identified across fabrication line. Authors had given explanation about to drawing the current state map of the process. The elements which are essentials to consider drawing current VSM, and how to calculate uptime of the process.

Ex : Cycle time, working time calculation, Value added time ,Non value added time etc.VSM Principal Guidelines and Value stream map drawing steps were briefly explained. Ex: usage of icons and symbols

Chetan Patell et al [19] This review paper addresses that, in today's manufacturing technology the lean tools are generally used to eliminating various categories of wastes present in the process. By implementing these tools company could enhance their profit level remarkably. Lean system is used to remove non value added activities from the value added activities. Added to this, it helps to concentrate on reducing lead time, inventory, space, utilization of human resource and money in better way. Lean manufacturing system not only impacting on an organization but also on customer and supplier also. By achieving zero defects, company would maintain zero delays in delivering the products, so it improves the satisfaction of the customer. VSM tool helpful for identification of wastes and reduction of same, continuous improvement in methods and process, it escalates the customer – supplier relationship by reducing lead time. Lean system offers various kinds of tools to increase the company productivity. While appropriate tools and methods of lean tools are applied, better final results could be achieved. Proper usage of 5S, OEE, VSM, JIT KANBAN and Pull systems along with proper time study and methodology drives company performance in to right path.

### III. METHODOLOGY

“Rother and Shook” defined Value Stream Mapping as ‘a pencil and paper tool that helps you visualize and understand the flow of material and information as a product makes its way through its value stream’. This methodology consisting of; literature review, problem identification, case study design and data analysis. In this paper, a Gear Manufacturing company is taken for case study. Analysis starts by identifying the problems in the manufacturing process and ends with generating solutions for the process improvement. Based on the data available in the shop floor processes, analysis began by studying the flow of the process, with the help of VSM models to determine and explain the details of the problem. Further to this, other important lean tools were used to complete of its manufacturing problem. 5S is used as a general framework for process improvement and lean tools in each phase and fishbone diagram or Ishikawa diagram were used for root cause analysis. As all manufacturing sectors know that, without using 5S it would be impossible for VSM model to go further because it acts as an indicator for future process path. So 5S acts as basic platform in kind of organizations. In addition, this study focuses on employee involvement and motivation were used to change the organization work culture. Flow of information related to production is classified as; 1. Material Flow, 2. Information Flow [20]. VSM is the only process which includes both flows in current and future state maps and help establish a relation between them. Initial stages of VSM consist of mapping the current state of the manufacturing plant. The current state is studied to identify wastes and bottleneck processes present in the process. Appropriate solutions are proposed to eliminate wastes, based on which a future state map is created. Data Collection, Drawing Current State Map, Identify and Eliminate wastes (MUDA), Future State Map, Implementation / Recommend actions.Look for the three forms of waste (MURA, MURI, and MUDA). Muda (non- value-adding work), Muri (overburden) and Mura (unevenness) [3] .It is also beneficial to calculate Takt time for comparison to the actual process time once the VSM is complete. The Takt time is the rate at which the customer actually demands product.

The methodology flow to accomplish the project objective is represented below into five parts. Fig 3.1 shows the methodology of VSM.

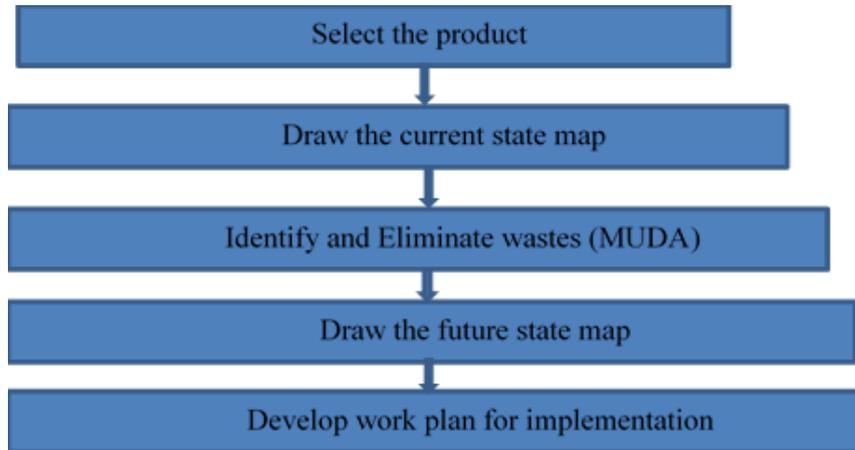


Fig 3.1: Methodology steps in value stream mapping

**IV. CASE STUDY / EXPERIMENTAL AND RESULTS**

The case study was taken where the manufacturing control process improved by using value stream mapping (VSM) methodologies. The manufacturer of the gear is the place conducted case study. Based on the identification of the activity P. Hines and D. Taylor, the types of activities are classified into two types, value-added (VA), and non-value added (NVA). Waste was eliminated by reducing the downtime during process set up with the help of time study along with change of working process. The VSM starts with a systematic approach, begun with the current state, preparing a process map to identify the inefficiencies, waste and draw the future state map with the achieved results.

**Preparation of Current state map:**

The current state map shows the current situation of the company. Specific data’s collected such as operation performed, flow of work and necessary information. Specific graphical symbols are used to draw the VSM. The following inputs used to plot the Current State Map. Past data’s collected from the company production log book to draw current VSM such as Selected Product Flow Process, Customer requirement, Supply schedule Sequence of operation, Number of working hours, shifts and breaks, Cycle time, Setup time, Loading and unloading time or change over time, Shifts worked and Net available working time, Number of operators, Suppliers raw materials details from purchase department, Rejection details and Inventory details from stores.

Table 4.1 Process sequence and Machine used in 21 Teeth Helical gear manufacturing

S.N	Sequence of process	Machine used
1	Stress Relieving Process	Bogie Hearth furnace
2	Facing	Lathe -1
3	Turning for Hobbing	CNC Lathe STC 25
4	Gear Hobbing	CNC Hobbing m/c
5	Fitting & Deburring	Manual
6	Case Hardening (Heat Treatment)	Gas furnace
7	CLR turning(Case Layer removal)	Lathe
8	Drilling	Radial Drilling M/c
9	Tapping	Manual
10	Case Hardening	Heat treatment Furnace
11	Shot blasting	Shot blasting m/c
12	Finish Turning	CNC turning m/c
13	CG (Cylindrical Grinding)	CG m/c
14	Gear Grinding ( final Finishing )	Nikes ZE 1200
15	Final inspection	Manual
16	Packing	Manual



**PROCESS FLOW CHART: Part Name: 21 TEETH PINION GEAR:**

Process flow chart for Pinion Gear 21teeth is shown in fig 4.1

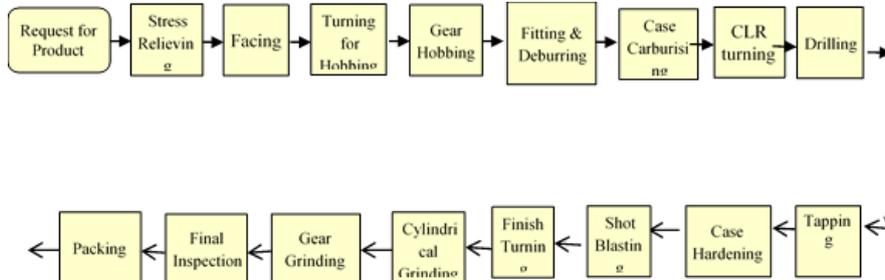


Fig 4.1 Flow Process Chart of Gear teeth

**Company working timings details as follows [18]**

1. Working time for shift I<sup>st</sup>, II<sup>nd</sup> and III<sup>rd</sup>: 8 hrs
2. Shifts per day : 3
3. Breaks for each shift (Lunch) : 30+30+30 = 90 mins
4. Number Of Tea breaks per shifts : 1
5. Tea break time pershifts: 5 mins , total time for 3 shifts : 15 mins
6. Available working time per day: (8X 60X 3) – Break time =1440 mins -105 mins= 1335 mins (22.25hrs)
7. Except Tapping and Fitting all other operations available working time: 22.25hrs
8. Tapping and Fitting operations works for only in the 1<sup>st</sup> and 2<sup>nd</sup> shifts

So Available working time: 8X60X 2-35X2 = 960 – 70 mins = 890 mins (14.83 hrs)

**CYCLE TIME FOR EACH PROCESS IN GEAR MANUFACTURING:**

Time study is a basic method or technique to observing and recording the time required to do each job or a product, it measures the time necessarily required for a job to be completed using the stop watch method. This is carried out by the industrial engineer. Manufacturing cycle time refers to the time required to covert raw materials into finished goods. It is also known as throughput time. Technically, it is the time length from the start of production to the delivery of the final products. Process time refers to the time used to actually work on the product. Normally procedure followed in the time Study activity is initiated with stop watch method. The numbers of observations are conducted to determine average cycle time of each activity or operations. The below table 4.2 shows the value added and non-value added time of each process.



Table 4.2 Process sequence and cycle time for 21Teeth Helical gear manufacturing

S N	Sequence of activities	CT(Mins) VA	NVA CT( Mins)	Cycle time (min) : observations using stop watch(After current state map drawn)				Non Value added activities CT(Mins)
				From Record (Cycle time +Setting time)	Trial I	Trial II	Trial III	
1	Stress Relieving	520+20	30	520	520	520	520.00 +20	30
2	Facing	50+25	20	44.85	44.80	44.80	44.82+12	10
3	Turning for Hobbing	70+60	30	64.60	64.75	64.65	64.67+40	15
4	Gear Hobbing	80+70	25	76.70	76.82	76.75	76.75+55	18
5	Fitting & Deburring	60+10	20	30.5	32.5	32.0	31.67+5	10
6	Case Carburizing (Heat Treatment)	1480+20	20	1480	1480	1480	1480.00+20	20
7	Case Layer removal turning	180+60	40	172.5	171.8	172.4	172.20+35	20
8	Drilling	137+10	25	125.4	126.0	125.6	125.67+6	10
9	Tapping	20+5	5	16.00	16.20	16.00	16.06+5	5
10	Case Hardening	480+20	20	460	460	460	460.00+20	20
11	Shot blasting	10+10	5	10	10	10	10+5	5
12	Finish Turning	73+20	30	40.6	40.5	40.6	40.6+15	15
13	Cylindrical Grinding	120+25	40	105.8	106.2	106.3	106.1+15	22
14	Gear Grinding (Finishing )	40+15	15	40.0	40.0	40.0	40.00+10	8
15	Final inspection	30+5	10	30.0	29.0	29.0	30.0	10
16	Packing	10+5	10	08	08	08	08+02	10

**VSM Mapping: Current State Value Stream Mapping**

All data for the current state map were collected according to the approach recommended by Rother and Shook. Data collection for the material flow started at the purchase department, and worked all the way to the dispatch process, gathering information data such as inventory levels before each process, process cycle times (CTs), number of workers, and changeover (CO) times. Fig 4.2 shows the current value stream map of the process.

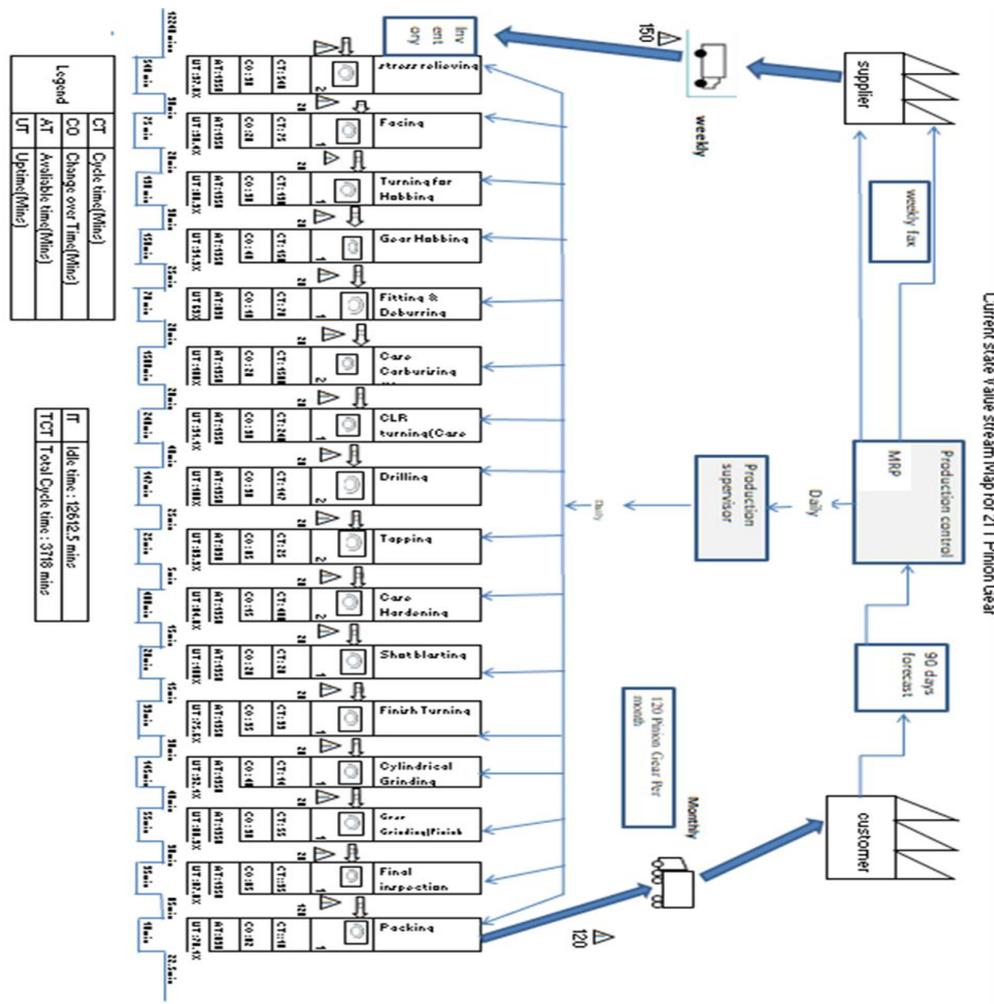


Fig: 4.2 show Current state value stream map for 21 T pinion gear.

**REJECTION/ DEFECTS DETAILS ANALYSIS :( Root cause Analysis)**

Root cause analysis is a useful process for understanding and solving a problem. It figures out what undesirable events are occurring. Then, look at the complex systems around those problems and identify key points of failures. Finally, this determines the solutions to address those key points or root causes.

Table 4.3: Name of the defects

S. N	Type of defect	Quantity	Percentage	Cumulative %
1	crack	25	16.67	16.67
2	Blow holes	12	8.00	24.67
3	Teeth misalignment	15	10.00	34.67
4	Oversized hole	8	5.33	40.00
5	Drilled hole Missed	5	3.33	43.33
6	Undersized hole	6	4	47.33
	<b>Total</b>	<b>71</b>		

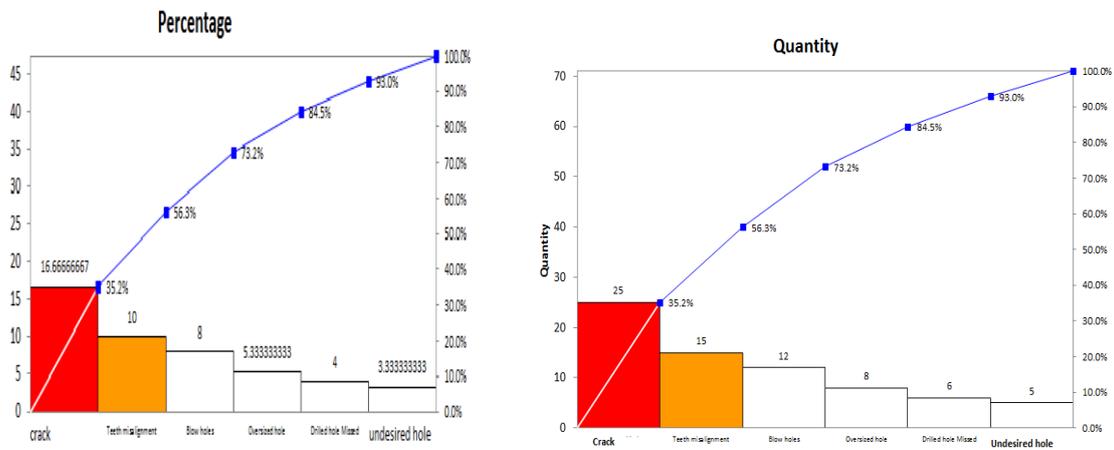


Fig 4.3: Pareto analysis

**WHY –WHY ANALYSIS: [21]**

Table 4.4 shows the RCA (Root cause) why –why analysis -) for Cracks found at outside dia of 21T Pinion gear. Table 4.4: why- why analysis for 21 T pinion gears

Process	waste	why 1	why 2	why 3	why 4	why 5
Grinding	Crack	Over heat due to Insufficient coolant used	Too large grinding cut generates frictional heat on tooth flank surface	Due to Unequal depth during hobbing	the operators does not comply with operating procedure	skill and operator accuracy is lacking
		Grinding wheel not dressed properly	wheel dressing frequency chart not provided	Wheel dressing frequency chart not followed. contained dust on the floor and the machine	Inadequate training. floor and machinery were rarely cleaned	the operator does not know about the cleanliness
		Depth of cut more	Incorrect grinding wheel choice	Specification not mentioned properly	Procedure not maintained.	the operator does not comply with operating procedure

**FISHBONE DIAGRAM:**

Quality issues and problem solved by using FISHBONE DIAGRAM.

FISHBONE diagram or ISHIKAWA diagram or cause and effect diagram are normally used to detect the product defect and quality defect prevention to identify potential factors at shop floor. Because of this tool also called route cause analysis. Fig 4.4 explains the crack found at the 21Teeth pinion gear.

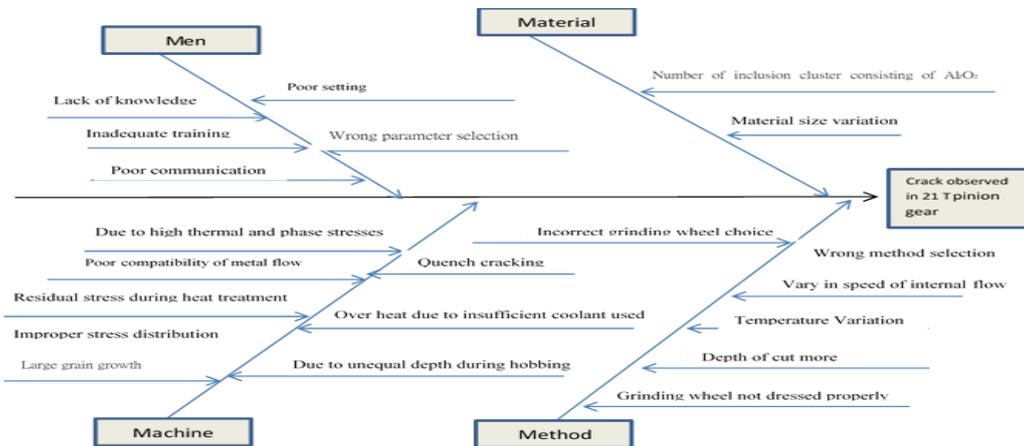
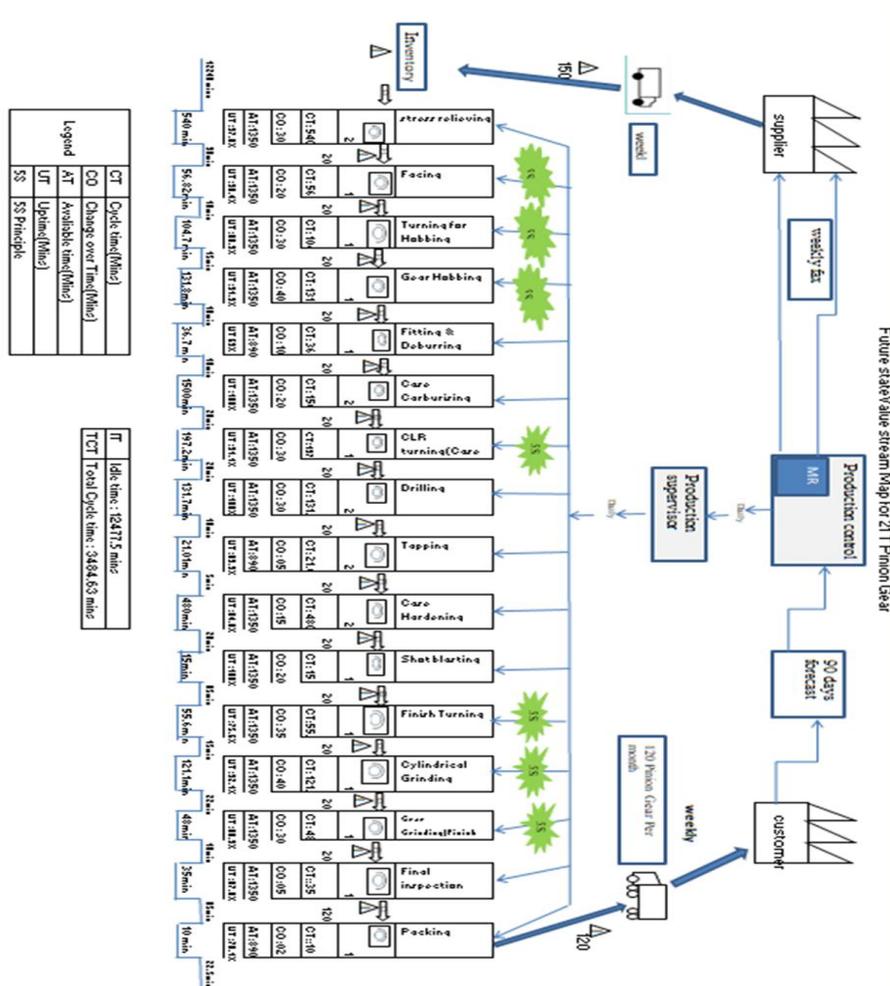


Figure 4.4 Fish-bone diagrams for root-cause analysis of crack defect

**FUTURE STATE MAP:**

The future state map illustrating the various modifications incorporated in the 21Teeth pinion gear manufacturing processes is shown in Figure 4.5



## V. RESULTS AND DISCUSSIONS

After the process analysis, wastes present in the manufacturing processes of pinion gear, various suggestions/recommendations for waste elimination have been developed in consultation with the production supervisor, which are presented as follows:

1. 5S – the concept of 5S is found vital for all the stages of operations, except heat treatment process. By assigning responsibility to the operator as a process owner said by Toyota Production system, process inspection was ensured by operator himself. Thereby inspection stages have been minimized. As a result of implementing this inspection concept, line inspectors are conducting only random inspection.

2. Revisit the programme at the finish turning operation and modified in the programme by increased spindle Speed from 80 to 100 rpm, feed from 1mm to 1.5 mm; thereby increasing productivity has been increase to 86.2 %.

3. Deburring operation was carried out by 2 persons manually with the help of files (Filing operation), now very small hand grinding machine dia with 3mm ball grinding wheel recommended to use to remove the burrs instead of filing wherever it's possible. So productivity increased from 3 components to 5 components per shift. Future state map, the total Value Added time for manufacturing the pinion is 58.08 hrs. Whereas the total idle Non Value Added time is 208 hrs.

### Production or industrial impact:

5S activities have been suggested for the operation stages mentioned in the previous section. Because improvement and deployment of cross functional team for effective 5S policy would enable the hygienic maintenance of shop floor. Currently, inspection activities have been carried out by the line inspectors. So operator is waiting for the clearance from the inspection department for some critical operations. So now responsibilities are deployed to operators needed for performing inspection. So it reduces the final inspection time. This would significantly eliminate the inspection operation.

### Lean thinking initiation:

Industry or organization has to form cross functional team. Cross functional team (CFT) in each industry has to identify and analyze bottle necks of production and provide suggestions accordingly. Then the concerned department has to initiate to provide training to their staff which integrated the tools which helps in identifying all type of wastes. Lean tools like value stream mapping (VSM), root cause analysis (RCA), find opportunities for improvement (OFI), and 5S etc. The objective of the management and concerned departments are to educate the key leaders within the organization about key concepts and also in order to manage the 5S, confirming training majorly to the shop floor staff and employees. The organization confirmed to focus on the 5S implementation over all the main process areas along with VSM, RCA and OFI tools. Communication plays a vital role in any organization. The interdepartmental communication gaps to be eliminated majorly among the trained employees and other staff. By motivating the employees, empowerment can be increased and it made to involve staff in all levels. The 5S team too started using the lean tools like '5 whys' 8D and 'fishbone diagram' to identify the root cause analysis for the problems. The management provided opportunities in independent leadership to employees to put efforts on lean and identify improvement where ever possible. Furthermore, the leaders can be identified the potential skills, and by giving training on lean tools, they would create a skilled environment in each department. This would enhance the performance of the organization.

### Managerial inference:

In modern competitive manufacturing system, managers are realizing that the cost reduction will pave the way for price reduction. This will help them to compete in the market. But, modern managers are facing challenges to identify the key areas, which can be considered for waste elimination. In order to achieve success in their field, they can use lean manufacturing tools. It offers VSM has a vital tool for their problems. By using this tool, it is possible to map the current status and consequently analyses for achieving waste elimination. In order to demonstrate this feature, the case study presented in this paper has shown. It shows, the way the managers can use VSM for identifying areas and applying this tool to waste elimination practice. It has been shown that the wastes and defects can be reduced which in turn improves the production time. In order to complete this job, the managers of SAN Engineering and Locomotives Ltd have to implement methodologies like 5S, VSM sincerely. Hence, VSM helps the managers to visualize the current level of wastes happening in the organization and the future possibility of reducing/eliminating them effectively. so hopefully will create healthy environment.

## VI. CONCLUSIONS

The results are evaluated to find out the most important tools necessary in initiating the lean thinking or lean system and executing for the organization, also what can be initiated in the SAN Engineering and Locomotives Co.Ltd to improve their Lean practices.

VSM tool has considered as a world class manufacturing tool in lean thinking system, which acts as a road map. Which has insisting the manufacturing sectors that, it is possible to reduce lead time by reducing waste through proper scheduling, better team work, planning, and training the workers and awareness in the workforce regarding the global competition. So VSM is applicable to any kind of industry for performance improvement. Lean system offers various kinds of tools to increase the company productivity. While appropriate tools and methods of lean tools are applied, better final results could be achieved. Proper usage of 5S, OEE, VSM, JIT KANBAN and Pull systems along with proper time study and methodology leads company performance in to right path. "VSM is one of the most important lean manufacturing techniques which are capable of tracking the wastes existing in the manufacturing processes" [Hines et al., 1999]. By implementing these tools company could enhance their profit level remarkably. Lean system is used to remove non value added activities from the value added activities. Added to this, it helps to concentrate on reducing lead time, inventory, space, utilization of human resource and money in better way. Lean manufacturing system not only impacting on an organization but also on customer and supplier also. By achieving zero defects, company would maintain zero delays in delivering the products, so it improves the satisfaction of the customer. VSM tool helpful for identification of wastes and reduction of same, continuous improvement in methods and process, it escalates the customer – supplier relationship by reducing lead time.

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