IMPLEMENTATION OF LEAN MANUFACTURING USING VALUE STREAM MAPPING

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ABSTRACT

The shop floor in the manufacturing sector has a numerous workstations. Each activity is interdependent, and it is necessary to carry out certain tasks according to the schedule to meet production demands. Value Stream Mapping (VSM) is a crucial tool that encompasses all activities necessary to transform raw materials into finished products. VSM analyzes manufacturing process with the help of available facilities, the flow of material, people, products, and information from the start to the completion of tasks. Value Stream Mapping technique involves flowcharting the steps, activities, material flows, communications, and other process elements that are involved with a process of transformation. In this respect, Value stream mapping helps an organization to identify the non-value-adding elements in a targeted process and brings a product or a group of products that use the same resources through the main flows, from raw material to the arms of customers. In this paper, a case study in the XYZ plastics industry which uses injection molding technology for manufacturing plastic spur gear is carried out. The objective of this research paper is to classify the types of activities in the manufacturing process of plastic spur gear, and to reduce the waste and non-value-added activities by proposing relevant techniques and measures. For this research, Process activity mapping (PAM), which is a vital tool in VSM for waste elimination has been implemented. A detailed time study of the mapping process is carried out from raw material to final product where the wastes and non-value-added activities are identified. The proposed improvement includes waste elimination techniques which helps to cut down the duration of non-value-added and necessary non-value-added activities thereby significantly reducing the production lead time.

Keyword: - *Value Stream Mapping, Current State map, Future State Map, Process activity mapping*

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1. INTRODUCTION

Lean manufacturing is one of the initiatives that many major businesses have been trying to adapt to remain competitive in an increasingly global market. Originating from the Toyota Production System, many of the tools and techniques of lean manufacturing like just-in-time (JIT), cellular manufacturing, total productive maintenance, have been widely used in discrete manufacturing. Applications have spanned many sectors including automotive, electronics, white goods, and consumer products manufacturing. The objective of this paper is to use a case-based approach to demonstrate how lean manufacturing tools when used appropriately, can help the process industry eliminate waste, maintain better inventory control, improve product quality, and obtain better overall financial and operational control [1].

XYZ plastics industry which is manufacturing plastic spur gear on large scale using injection molding technology has been chosen to illustrate the approach followed. Injection moulding is one of the most prevalent and capable processes for mass-producing complicated plastic parts with tight dimensional tolerances. It requires almost nothing, if any, finishing and assembly. It's a cyclic technique that involves forcing molten plastic into a chamber under pressure to mould it into the desired shape. The final shaping is achieved by cooling [2]. The flow behaviour of the plastic melt in the mould cavity must be well understood, and injection moulding machine process parameters must be selected based on flow behaviour characteristics, to produce good quality parts with excellent dimensional tolerance.

As an industry that has positioned itself in the field despite the growing competitors, this company is required to complete the order at the specified time and specific amount of goods. It would be much effective if they could reduce the production lead time which this industry finds difficult. In some instances few orders have to be delayed because the company is unable to complete the production on time. This delay is caused by work that is not per the procedure. By doing some interviews and research, the problem that affects the current condition of the manufacturing process can be identified.

In this approach of lean implementation, value stream mapping (VSM) is first used to map the current operating state of the company. This map is used to identify sources of waste and to identify lean tools for reducing waste. A future state map is then developed for the system with lean tools applied to it. Further comparisons are made with the current state and future state map to calculate if the proposed system has reduced the non-value added activities duration and waste to make sure if the proposed system is successful or not.

1.1 Problem Statement

The following are the statements that will be focused on this analysis,

- What is the current condition in the production process in VMS?
- How does the company improve its manufacturing process and eliminate wastes in the current production process?
- How is the improvement in the future VSM?

1.2 Research objectives

The research objectives are established to keep the research on track, so here are the objectives in conducting this research,

- To identify and analyze the company’s current condition using Value Stream Mapping.
- To classify the activities as value-added and non-value-added and eliminate non-value added activities.
- To define the results and application of the proper methods to reduce time and wastes in the current production process and its results.

2. LITERATURE REVIEW

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 to have a brief idea of the tools and techniques previously discussed and applied in their paper or journals and the obtained feasible results

2.1 Lean Manufacturing

Lean manufacturing is an important tool used across the industries in the recent scenario. At present the industries are facing a higher level of competition because of globalization. In this context, to remain and compete in the market, companies need to deploy certain tools and techniques which are useful to uplift their performance and to respond rapidly to the customer‘s needs. The fundamental concept of lean manufacturing is to provide a quality product while also ensuring that the product does not cost too much to the customer.

Hook and Stehn (2008) found that lean principles can be used in any business, and these principles are identifying the value stream map for every product, making production flow smooth without interference, the customers pull value from produces. According to **Hossain (2014)**, there five main lean principles which are:

- ✓ Identify the requirement of customers. Specify the necessary thing what is non-value added, what is the value-added from both customer perspective and company perspective.
- ✓ Specify the value stream of production, the design, order, production, products, and the whole system to highlight the non-value-added waste and reduce it.
- ✓ Ensure the remaining value-added process work continuously, create process without interruption, backflows, waiting, and wastes.
- ✓ Explain the pull system in the steps.
- ✓ Conduct efficient and effective management, and eliminate the number of process steps, information, and time.

Fig -1: Lean Production House

Regarding the study from Hossain (2014), lean is about reducing waste. These wastes are categorized into 8 types. Different kinds of production wastes can be concluded as follows:

Overproduction – Producing items more than required at given point of time i.e. producing items without actual orders creating the excess of inventories which needs excess staffs, storage area as well as transportation etc.

Waiting – Workers waiting for raw material, the machine or information etc. is known as waiting and is the waste of productive time. The waiting can occur in various ways for example; due to unmatched worker/machine performance, machine breakdowns, lack of work knowledge, etc.

Unnecessary Transport – Carrying of Work In Process (WIP) a long distance, insufficient transport, moving material from one place to another place is known as the unnecessary transport.

Over processing – Working on a product more than the actual requirements is termed as over processing. The over processing may be due to improper tools or improper procedures etc. The over processing is the waste of time and machines which does not add any value to the final product.

Excess Raw Material - This includes excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, the extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.

Unnecessary Movement – Any wasted motion that the workers have to perform during their work is termed as unnecessary movement. For example movement during searching for tools, shifting WIP, etc.

Defects – Defects in the processed parts is termed as waste. Repairing defective parts or producing defective parts or replacing the parts due to poor quality etc. is the waste of time and effort.

Unused Employee Creativity – Loosing of getting better ideas, improvement, skills and learning opportunities by avoiding the presence of employee is termed as unused employee creativity.

2.2 Value Stream Mapping

Shubham A. Kadam et al., stated that VSM is a lean manufacturing technique used to map the flow of materials and information required to convey a product to a consumer. VSM was created in 1995 to assist researchers in identifying waste in value streams and possibilities for improvement. It also determines the best trash removal path. It follows the flow of materials from client delivery to the end of the manufacturing process. It graphically chronicles the entire process and also collects data. Finally, a single page map called Value stream is produced, containing information such as cycle time, change over time, work-in-process (WIP) levels, and the number of operators.

VSM depicts the connections between manufacturing processes and the controls that are used to manage them, such as production scheduling and data interchange. Even in the flow of information, VSM is about removing waste. While value stream mapping is more difficult to create than other process maps, it has the advantage of containing significantly more data than a regular map. Manufacturing businesses must reinvent and redesign their production processes in response to the competitiveness and challenges of today's marketplaces. A corporation can use VSM to see the complete process in both it’s current and intended future states. VSM is a visual presentation of the entire value stream from customer order entry through purchasing, manufacturing, and shipping of the finished product in a facility.

VSM 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 them. There are four steps used in the Value Stream Mapping Cycle which is depicted in the figure below

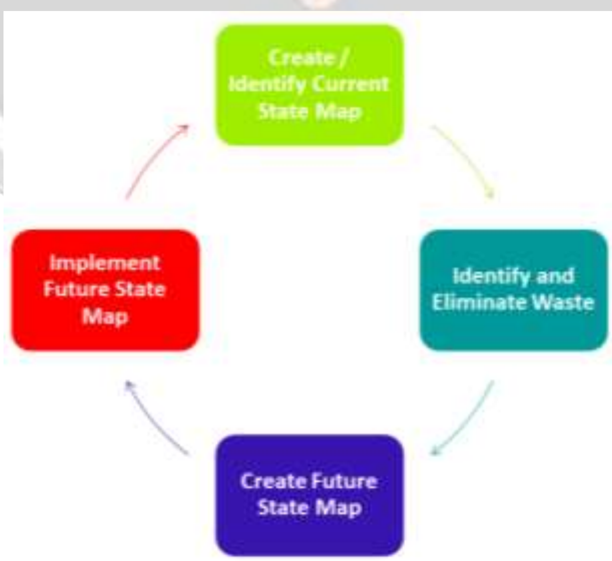

Fig -2: Sequence of VSM activities

Santosh (2014) stated that to make Value Stream Mapping, there are several data that must be collected. This data is collected to create the process and material flow, information flow, and timeline. This data are:

1. Information about the suppliers, actual demand in daily/month/year, forecast demand, cycle issue, ordering frequency, and detailed shipment information.
2. Data about suppliers, the cycle of order, raw materials, lead time, procedure, and order.
3. Working hours, shifts, overtime, break, and holidays.
4. Production control information system.
5. Production process data, the workstation characteristic, total operator, machine and equipment, process flow, defect rate, set up time and cycle time.
6. Value Added Time and Non-Value Added Time.
7. Takt time calculation is required.

   Takt time = $[\frac{Available\ working\ time}{Daily\ demand}]$

2.3 Timestudy

Meenakshi., & Varadarajan, Y.S. (2020) stated that 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 stopwatch method. This is carried out by the industrial engineer. Manufacturing cycle time refers to the time required to convert 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 the stopwatch method. Number of observations are conducted to determine the average cycle time of each activity or operation.

2.4 Process Activity Mapping

Process activity mapping (PAM) is used to find out all the activities that take place during the production process and then classify those activities based on the type of waste. This tool aims to eliminate unnecessary activities, identify whether a process can be more efficient, and look for improvements that can reduce waste **(Girish, et al., 2012)**. Process activity mapping consists of five steps that need to be done, namely:

1. Identify the process flow and do the initial analysis.
2. Identifying waste.
3. Consider the rearrangement of sequence processes to be more productive.
4. Consider a better flow pattern
5. Consider eliminating hard work and only what really matters **(Hines & Rich, 1997)**

Table -1: Process Activity Mapping template

S.NO	STEP	ACTIVITY (VA/NVA/NNVA)	MACHINE	DISTANCE (M)	TIME (MINS)	PEOPLE	O	T	I	S	D

Whereas

O = Operation	D = Delay
T = Transportation	VA = Value Added
I = Inspection	NVA = Non-Value Added
S = Storage	NNVA = Necessary Non-Value Added

3. RESEARCH METHODOLOGY

The following framework determines the method used for analyzing this research.

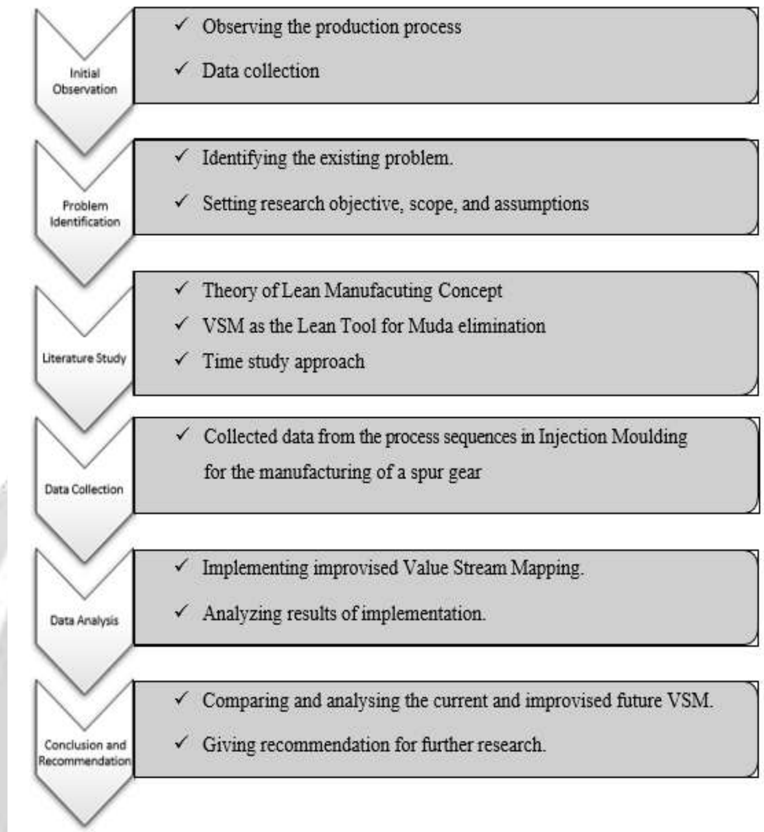

Fig -3: Research Methodology Framework

4. DATA ANALYSIS AND INTERPRETATION

The case study was taken where the manufacturing control process could be improved by using value stream mapping (VSM) methodologies. Based on the identification of the activities they are classified into three types, Value-Added (VA), Non-Value-Added (NVA), and Necessary Non-Value-Added (NNVA) activities. Waste elimination was done by reducing the duration of downtime with the help of time study along with process activity mapping. The VSM starts with a systematic approach, beginning with the current state, preparing a process map to identify the inefficiencies, waste and draw the future state map with the achieved results.

4.1 Injection molding process

The injection moulding process begins with a polymer being fed from a hopper into a heated barrel, after which the melted plastic is injected into the mould under high pressure. During this process, steady pressure is applied to both plates of the injection moulding machine (moving and fixed platens) to close the mould while the plastic is injected subsequently the product is then allowed to cool, which facilitates the solidification process. After the object has taken shape and has cooled sufficiently, the two plates will detach to separate the mould tool, a process known as mould opening. Finally, the plastic part is ejected or removed from the mold. After the ejection of the part, the process will repeat itself **(2011, Samson Teklehaimanot).**

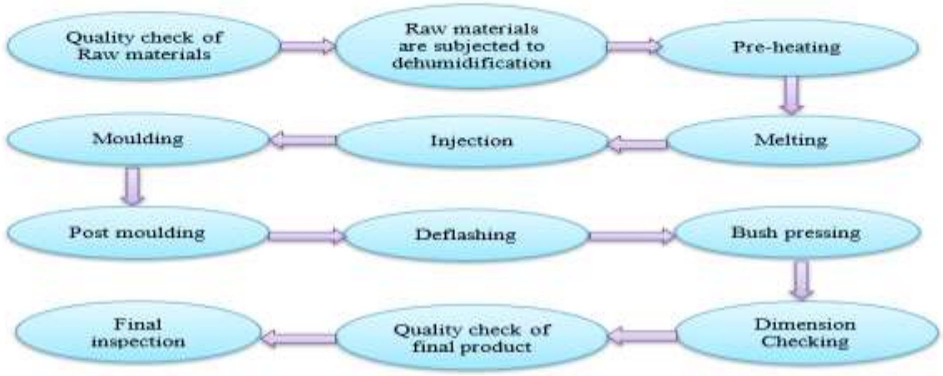

Fig -4: Injection Moulding process Flowchart

4.2 Company working time details

Duration of shift : 8 hours = 480 mins
Overtime shift: 3 hours = 180 mins
Lunch break time: 30 mins
Tea break time: 10 mins
Available working time per day: Total Shift time – Break time = 660 mins - 40 mins = 620 mins
Hence the total working time available is 10 hours 20 minutes.

4.3 Time study processing

The Time study technique is implemented for observing and recording the time required to accomplish each activity or product. The Stopwatch method to measure the time necessary for a job to be performed was done under the supervision of the industrial engineer. The time it takes to turn raw materials into completed goods is referred to as the manufacturing cycle time. The time spent operating on the product is referred to as process time. The following table shows the cycle time and process time taken during the manufacturing of one lot (200 Pcs) plastic spur gear in the company.

Table -2: Current Process sequence, cycle time+setting time for plastic spur gear manufacturing

S.No	Sequence of activities	Cycle Time + Setting time (Minutes)			Average Cycle Time + Setting time (Minutes)	Average Duration of NVA (Minutes)
		Lot 1	Lot 2	Lot 3		
1	Dehumidification	120+2	135+3	125+8	126.66+4.33	2.43
2	Pre – heating	4+4.06	4+6.32	4+3.13	4+4.50	4.34
3	Melting	126+12	132+9	142+7	141.33+9.33	2.31
4	Injection	318+5.4	308+7.2	314+6.2	313.33+6.26	5.20
5	Holding	30+3.6	33+4.5	32+4.35	31.66+4.15	1.22
6	Cooling	92+1.5	100+2.1	96+1.2	96+1.6	2.20
7	Ejection	7+1.5	9+0.75	12.36+1.25	9.45+1.16	3.95
8	Drilling	90+7.35	80+5.12	95+10.33	88.33+7.6	7.25
9	Tapping	30+4.23	20+3.52	25+5.39	25+4.38	2.42
10	Metal insertion	20+9.47	35+5.32	30+4.32	28.33+6.37	8.36
11	Deflashing	60+1.00	75+1.25	70+2.14	68.33+1.46	9.37
12	Dimension check	90+2.10	100+2.52	80+2.25	90+2.29	2.45
13	Final inspection	20.44+2.28	23.55+2.37	25.11+2.36	23.03+2.33	2.11
14	Packaging	13.54+1.15	12.34+1.44	11.57+1.39	12.48+1.33	0.81

4.4 Current State Value Stream Mapping

All data for the current state map were collected. Data collection for the material flow started at the purchasing department, and worked all the way to the dispatch process, gathering information data such as process sequences, process cycle times (CTs), uptime calculations, machinery facilities, number of workers, etc., Fig-5 shows the current value stream map of the process.

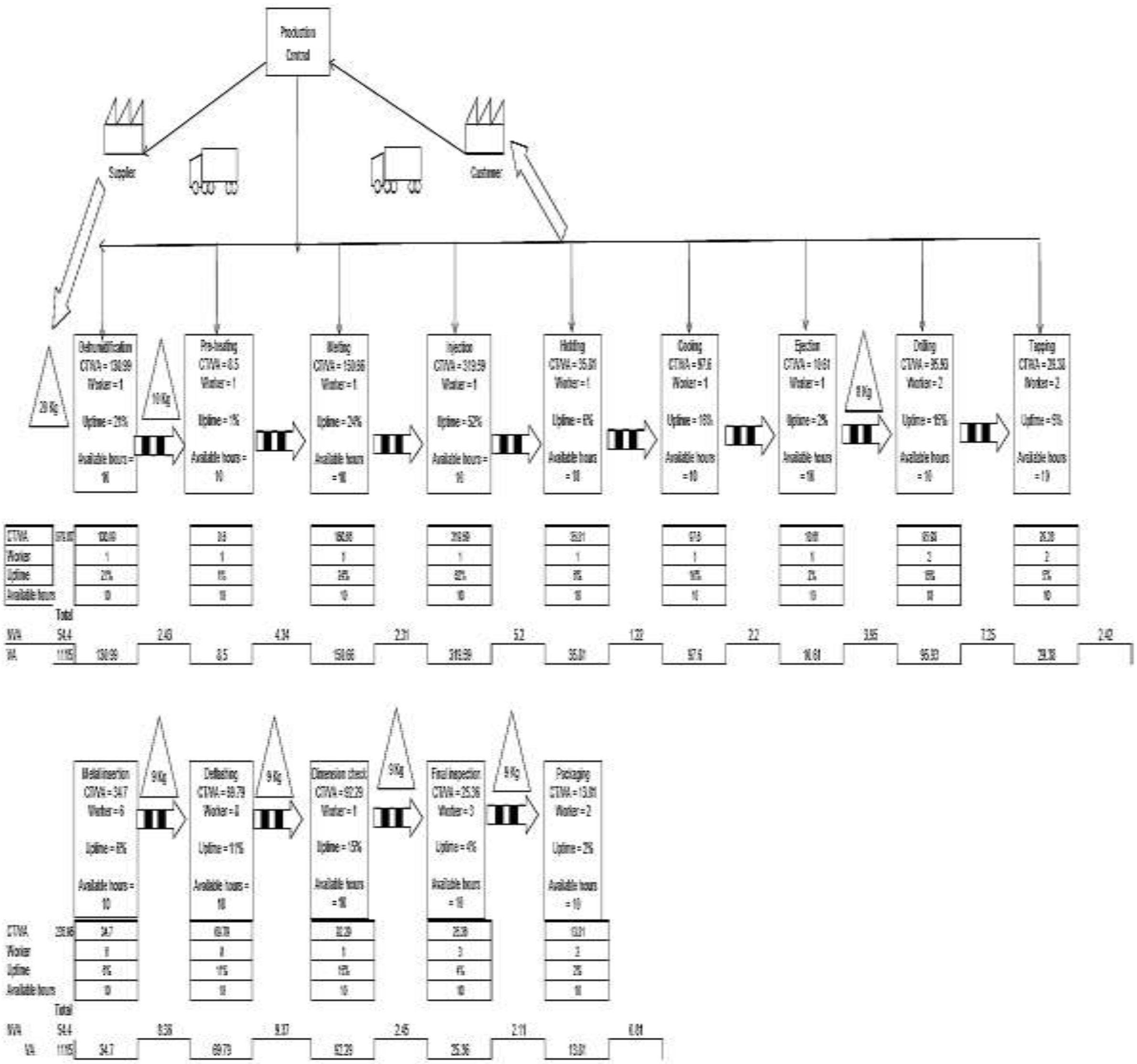

Fig -5: Current State Value Stream Mapping

4.5 Process Activity Mapping

Process activity mapping involves the preliminary analysis of the process followed by the detailed recording of all the items required in each process. The process sequences have been categorized in terms of a variety of activity types (operation, transport, inspection, and storage). The current condition of the machine and workstation used for each of these activities is recorded, together with the distance moved, time duration and the number of people involved everything is tabulated below in Table-3 Process Activity Mapping.

Table -2: Process Activity Mapping

S.No	STEP	ACTIVITY	MACHINE	DISTANCE (M)	TIME (MINS)	PEOPLE	O	T	I	S	D
1	Raw materials	VA	Reservoir	-	-	-				✓	
2	Raw material transfer from store to moulding section	NNVA	-	6.09	5.00	2		✓			
3	Dehumidification	VA	Hot air dryer	-	130.99	1	✓				
4	Waiting for Process sheet approval	NVA	-	-	5.42	1					✓
5	Pre – heating	VA	Hopper	3.66	8.50	2	✓				
6	Melting	VA	ENGEL 80 Ton Injection Moulding Machine	-	150.66	1	✓				
7	Injection	VA	ENGEL 80 Ton Injection Moulding Machine	-	319.59	1	✓				
8	Holding	VA	ENGEL 80 Ton Injection Moulding Machine	-	35.81	1	✓				
9	Cooling	VA	ENGEL 80 Ton Injection Moulding Machine	-	97.6	1	✓				
10	Ejection	VA	ENGEL 80 Ton Injection Moulding Machine	-	10.61	1	✓				

S.No	STEP	ACTIVITY	MACHINE	DISTANCE (M)	TIME (MINS)	PEOPLE	O	T	I	S	D
11	Transfer of molded pieces to post moulding section	NNVA	Hand Trolley	15.84	5.51	1		✓			
12	Drilling	VA	Drilling machine	-	95.93	2	✓				
13	Tapping	VA	-	-	29.38	2	✓				
14	Metal insertion	VA	-	-	34.7	6	✓				
15	Transfer of products to deflashing section	NNVA	-	4.6	1.34	1		✓			
16	Deflashing	VA	-	3.04	69.79	8	✓				
17	Dimension check	VA	Gauges and Coordinate Measuring Machine (CMM)	-	92.29	1			✓		
18	Transfer of finished goods to quality section	NNVA	-	18.28	6.24			✓			
19	Final inspection	VA	-	-	25.36	3			✓		
20	Packing	VA	-	-	13.81	2	✓				

4.6 Process Activity Mapping results

In the manufacturing process of plastic spur gear production, the total time duration for the completion of the entire process is 1138.53 minutes. These activities are categorized into three types. Some activities result in adding value (value-added activities / VA) consisting of 14 processes with a time duration of 1115.02 minutes or 87.60% of the total operations. Value-added activities tops in contribution. Then activities that are pretentious but do not add value (Necessary but Non-Value Added / NNVA) consist of 4 transportation processes with a time of 18.09 minutes or 1.58% of the total operations. Non-Value Added activity consists of 1 delay process with a total time of 5.42 minutes or equal to 0.48% of the total operations.

4.7 Waste identification and its elimination techniques

1) Pre-heating

The hopper is present on the very top of the machine. It is not easily reachable hence a ladder is needed. There is only one ladder in the molding unit so each time the operators had to take the ladder to their machines whenever needed to fill the materials into the hopper. This results in unwanted movement of operators here and there inside the molding unit. Most of the operators are ladies. Hence they find it difficult to climb on the ladder to reach the hopper. So the supervisor goes in search of a male operator in the other molding units to do this task. This results in unwanted movement and also until this process is done the operators and machines are idle.

Waste identified: Motion and waiting
Reason: Lack of proper equipment
Elimination Technique: Replacement of ladder with Portable Stairs

2) Waiting for Process sheet approval

There is only one supervisor for all six moulding units. So the operators had to wait for their turn to get the process sheet approved. Until then the operators and machines are idle.

Waste identified: Slow approval process
Reason: Insufficient manpower
Elimination Technique: Proper Manpower planning

3) Melting

The setup panel is not functioning properly. So it consumes more time whenever setting the required parameters. Often values assigned to all parameters get changed. So again assigning values for the parameters has to be done. This increases the setup time to a wide extent increasing non-value added activities duration.

Waste identified: Excess processing duration
Reason: Machine error and Lack of maintenance
Elimination Technique: Total Productive Maintenace (TPM)

4) Injection

The injection process has the highest processing time of all operations. During the run, the molten plastic material doesn’t fill in the mould cavity completely. Machine gets stuck in between and takes more time to complete the process than the usual cycle time. Though the improper condition of the machine is updated relevant action has not been taken.

Waste identified: Excess processing duration
Reason: Machine error and Lack of maintenance
Elimination Technique: Total Productive Maintenace (TPM)

5) Ejection

Usually, ejection of each product takes only 1.5 seconds but due to machine fault, it takes 3 to 5 seconds for ejecting each product which increases the cycle time considerably.

Waste identified: Excess processing duration
Reason: Machine error and Lack of maintenance
Elimination Technique: Total Productive Maintenace (TPM)

6) Defects in products

There are flaps of thin extra plastic material at the edges of the finished product which is called a flash or spew or burrs. These defects can affect the aesthetics of the finished product. Though they can be removed in the deflashing process this defect significantly increases the processing time. Sometimes products with severe flashes are even rejected thereby increasing the rejection rate.

Rejection/ Defects Details Analysis: (Root Cause Analysis) / Why –Why 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 -3 shows the RCA (Root cause Analysis) / why –why analysis for flashes found at outside dia of the plastic spur gear.

Table -3: why- why analysis for flashes defect in the plastic spur gears

PROCESS	WASTE	WHY 1	WHY 2	WHY 3
Injection	Defects	Poorly designed or worn and degraded mold	Excessively high mold temperature or injection pressure	Insufficient clamping force of the plates containing the resin.
Solutions		Retool or redesign the mold if plates don't fit together properly or allow material to flow outside the channel	Adjust mold temperature, injection pressure and ventilation to improve material flow	Increase plate clamping force to confine material flow to the channel

7) Transfer of molded pieces to post moulding section

The moulding units are located on the ground floor while the post moulding section is located on the second floor the WIP products are transferred by a worker using a hand trolley. He finds it hard to move the hand trolley over the ramps which consumes more time to complete the movement of WIP goods.

Waste identified: Transportation and Waiting
Reason: Poor workstation layout
Elimination Technique: Implementing a goods elevator

8) Transfer of finished goods to quality section

After dimension check, the finished products from the deflashing section located on the second floor are transferred to the quality section located on the ground floor. The worker transfers the products using a hand trolley over the ramps consuming more time. This increases the transportation process duration

Waste identified: Transportation and Waiting
Reason: Poor workstation layout
Elimination Technique: Implementing a goods elevator

9) Packing

The materials and equipment for the packing process are not well organized, so the workers move inside the section in search of required tools which results in unwanted motion. This also increses the initial setup time.

Waste identified : Motion
Reason: Bad housekeeping
Elimination Technique: Implementation of 5S

4.8 Proposed Improvement

The proposed waste elimination techniques are implemented in the manufacturing process. The Process Activity Mapping drafted after the proposed methodology implementation consists of the summary of analysis and shows the results of improvement. The comparison between current Value Stream Mapping and Future Value Stream Mapping was conducted to show if the research is successful or not.

4.9 Future State Value Stream Mapping

After the implementation of the proposed methodology, there is a significant reduction in the processing time leading to a reduction in the lead time. The aim of reducing the duration of non-value-added and necessary non-value added activities have been achieved. The future state value stream map illustrating the various modifications incorporated in the plastic spur gear manufacturing processes is shown in Figure 6

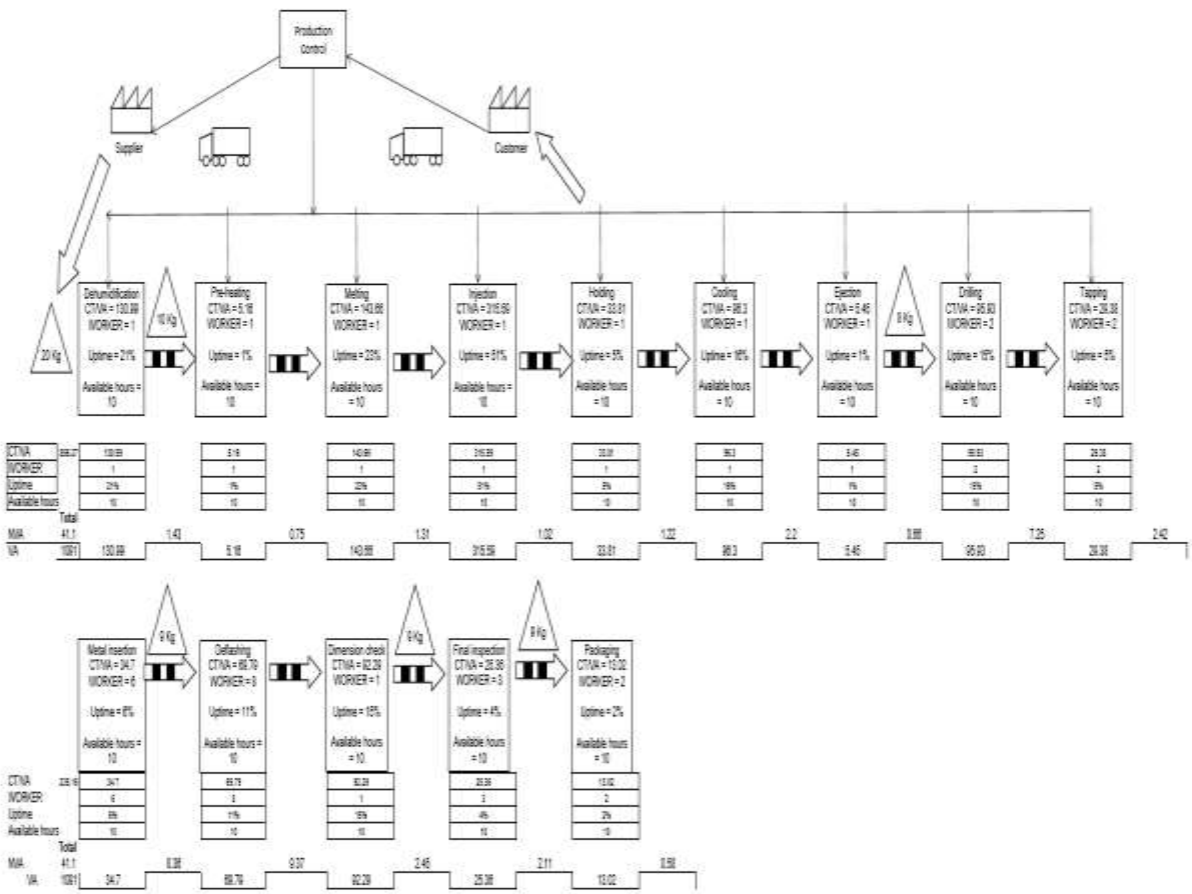

Fig -6: Future State Value Stream Mapping

4.10 Process Activity Mapping results after the implementation of the proposed methodology

After the implementation of the proposed methodology in the plastic spur gear production, the total time duration for the completion of the entire process is 1099.42 minutes. These activities are categorized into three types. Some activities result in adding value (value-added activities / VA) consisting of 14 processes with a time duration of 1089.46 minutes or 99.97% of the total operations. Value-added activities tops in contribution. Then activities that are pretentious but do not add value (Necessary but Non-Value Added / NNVA) consist of 4 transportation processes with a time of 8.51 minutes or 0.77% of the total operations. Non-Value Added activity consists of 1 delay process with a total time of 1.45 minutes or equal to 0.14% of the total operations.

4.11 Summary of the results between current and future process activity mapping results

Current Process Activity Mapping	Future Process Activity Mapping
The processing duration is 1138.53 minutes which is about 19 hours.	The processing duration is 1099.42 minutes which is 18 hours 20 minutes.
Necessary but Non-Value Added activities duration is 18.01 minutes	Necessary but Non-Value Added activities duration is 8.51 minutes
Non-Value Added activities duration is 5.42 minutes.	Non-Value Added activities duration is 1.45 minutes.
Production lead time is 2.36 days which is about 56 hours 38 minutes.	Production lead time is 2.33 days which is about 55 hours 55 minutes

4.12 Results and discussions

- ✓ The proposed methodology has attained its objective by eliminating the duration of non-value added and necessary non-value added activities to the maximum extent thereby reducing the lead time from 2.36 days to 2.44 days which has reduced 43 minutes from its original lead time.
- ✓ The simple introduction of goods elevator has drastically reduced the transportation time from 18.01 to 8.51 minutes which has eliminated necessary non-value-added activities duration for about 9 minutes.
- ✓ Proper Manpower planning is indispensable as in this case the only delay was waiting for the process sheet approval. This was due to improper manpower planning. Assigning sufficient supervisors in the molding units eliminates the NVA duration to the maximum extent.
- ✓ Proper equipment maintenance and frequent inspection help in discovering the machine errors soon as it occurs and helps in rectifying them thereby preventing the occurrence of the slow production process. This process plays a major role as the higher cycle time in the process sequences was due to machine errors and lack of maintenance.

5. CONCLUSIONS

The company's current state and process activities were analyzed and formulated from the collected data using value stream mapping. Before the implementation of the proposed methodology, the Non-value-added and Necessary Non-value-added activities duration were high. Moreover, the cycle time of each process was high due to lack of proper maintenance leading to machine errors resulting in the slow production process. There are seven Value Stream Mapping tools for the elimination of lean wastes. The majority of the wastes were under waiting, transportation and unnecessary motion. Among which the suitable tool having the highest correlation and usefulness for eliminating these wastes is the Process Activity Mapping tool. The Process activity mapping (PAM) is used to find out all the activities that take place during the production process and then classify those activities based on the type of waste. This tool aims to eliminate unnecessary activities, identify whether a process can be more efficient, and look for improvements that can eliminate waste. Using Process Activity Mapping tool the activities were categorized as Value-added, Non-value-added, Necessary Non-Value-Added activities and the reasons for the wastes were identified. After analyzing the various lean tools and techniques the relevant and efficient waste elimination techniques are selected. Based on these findings the improvised methodology was proposed. After the implementation of the proposed methodology improvised and future state value stream map and process activity mapping were drafted. Analysis of the future state map and process activity mapping was carried out to determine if the proposed methodology is successful and satisfied its objectives of minimizing wastes and production lead time. The proposed methodology was effective and has significantly reduced the production lead time from 2.36 to 2.33 days thereby eliminating the NNVA and NVA duration to the maximum and possible extent.

6. RECOMMENDATION FOR FUTURE RESEARCH

- ✓ To develop standardized work procedures to ensure in acquiring good and stable work results.
- ✓ To analyze the results of implementing the proposed methodology and make further improvements wherever needed.

7. REFERENCES

[1] Abdulmalek, F. A., & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. International Journal of Production Economics, 107(1), 223–236.

[2] ÖZdemir, A., Uluer, O., & Güldaş, A. (2004). Flow front advancement of molten thermoplastic materials during filling stage of a mold cavity. Polymer Testing, 23(8), 957–966.

[3] Mehat, N. M., Kamaruddin, S., & Othman, A. R. (2013a). Modeling and Analysis of Injection Moulding Process Parameters for Plastic Gear Industry Application. ISRN Industrial Engineering, 2013, 1–10.

[4] Höök, M., & Stehn, L. (2008). Applicability of lean principles and practices in industrialized housing production. Construction Management and Economics, 26(10), 1091–1100.

[5] Mintz, T. B. (2003), "Lean Manufacturing: Processing Buzzword or Operational Lifesaver?" Engineered Wood Journal, Vol. 6, No.1, pp. 12-15.

[6] Lixia, C., and Bo, M. (2010), "Why Most Chinese Enterprises Fail in Deploying Lean Production", Asian Social Science, Vol. 6, No. 3, pp. 52-57.

[7] Todd, P. (2000), "Lean Manufacturing: Building the Lean Machine," Advanced Manufacturing, http://www.advancedmanufacturing.com/Lean_mfg/building-side3.html, September 12.

[8] Drew, J., Blair, M., and Stefan, R. (2004), Journey to Lean: Making Operational Change Stick. Gordonsville, VA, USA: Palgrave Macmillan. p. 5-25

[9] Hossain, M. (2014). An Approach to Reduce the Manufacturing Waste and Improve The Process Cycle Efficiency of a Food Processing Industry by Using Lean Six Sigma Model. Bangladesh University of Engineering and Technology.

[10] Shubham A. Kadam1 et al., Value Stream Mapping On Gear Manufacturing Company, International Journal of Advance Research, Ideas and Innovations in Technology. ISSN:2454-132X (Volume3, Issue2)

[11] Rother, M., and Shook, J. (1999), "Learning to see Value Stream Mapping to added value and eliminate muda" International Journal of Physical Distribution & Logistics Management, Vol. 30, No. 9, pp. 731-749.

[12] Santosh B. Dighe, Abhay Kakirde. (2014), "Lean Manufacturing Implementation Using Value Stream Mapping: A Case study of Pumps Manufacturing Company", International Journal of Science and Research (IJSR), Volume 3 Issue 6, June 2014, 2492 – 2498.

[13] Hines, P., & Rich, N. (1997). The seven value stream mapping tools. International Journal of Operations & Production Management, 17(1), 46–64.

[14] Meenakshi., & Varadarajan,Y.S. (2020). Lead Time reduction using Value Stream Mapping for a Mechanical Gear Manufacturing Firm. International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), e-ISSN: 2319-8753, p-ISSN: 2320-6710 (Volume 9, Issue 5)

[15] Rother, M., and Harris, R. (2008), "Creating Continuous Flow an Action Guide for Managers, Engineers and Production Associates", One Cambridge Center, Cambridge USA: Lean Enterprise Institute. pp. 13-15.

[16] Shah, R., and Ward, P. T. (2003), "Lean manufacturing: context, practice bundles and performance", Journal of Operations Management, Vol. 21, pp. 129-149.

[17] Girish, et al., (2012), "Application Of Process Activity Mapping For Waste Reduction A Case Study In Foundry Industry", International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.5, pp-3482-3496.

[18] Teklehaimanot. (2011). Simulation and Design of a plastic injection mold, (Master thesis, Arcada University, Finland).Retrieved from https://www.theseus.fi/bitstream/handle/10024/41114/Samson%20Teklehaimanot%20Final%20Thesis.pdf