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Study on Application of Lean Manufacturing Tools for Performance Improvement

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Abstract
Lean Manufacturing is a philosophy of operations management that provides a set of tools and techniques to analyze the manufacturing of a product from its inception to the customer. This approach focuses on reducing the wastes at various points without affecting its quality and performance through the application of various tools. This paper attempts to study the case of a large steel mill. This paper lists out the various processes and the different stages of Manufacture of Steel. After this, the methodology used for the Value Stream Mapping (VSM) has been listed. Finally, the Current State Map of Steel Manufacturing Process has been drawn and the map has been analyzed in detail.

1. Introduction

Global competition has prompted many companies to adopt new manufacturing approaches such as lean manufacturing in order to be more competitive [1]. Increasing consumer expectations has also made the companies realise this to survive and thrive. The concept of lean has also been utilized in Service sectors.

The objective of the paper is to cover the available literature published in referred journals, conferences and books on VSM and its applications in different areas all over the world from 1990 onwards. The case study of a large steel mill is used to analyse and explain VSM. It demonstrates how Value Stream Mapping can help industries to eliminate waste, maintain better inventory and have an overall bett er control of the operations management.

The goal has been reached by fulfilling following objectives:

- Draw the current state map
- Identify value adding and non-value adding activities.
- Improve product quality within processes.
- Reduce wasteful operations, i.e. transportation, over-processing, idle-time, etc.
- Simplify and standardize working methods

The literature review provides a comprehensive presentation of the Lean Production system, its origin and development. Only the Value Stream Mapping tool from Lean principles has been used.

2. Literature Review

In this section different lean tools and specifically value stream mapping will be discussed. Womack et al. (1990) coined the term 'lean production' in their book "The Machine That Changed the World"[2]. This concept originated in Japan after the Second World War when Japanese manufacturers realized that they could not afford the huge investments required to build facilities similar to those in the USA. They started questioning some of the basic assumptions in business and manufacturing, and began their journey of refining manufacturing processes to minimize waste in all aspects of operations. Lean manufacturing initiatives, which are also known as the Toyota production system (TPS), were originated by Ohno and Shingo at Toyota [3].

A brief description of the most common lean tools is given below (Monden, 1998; Abdulmaleka, Rajgopal, 2006) [4] [5];

- **Cellular Manufacturing:** Organizes the entire process for a particular product or similar products into a group (or ''cell''), including all the necessary machines, equipment and operators. Resources within cells are arranged to easily facilitate all operations.
- **Just-in-time (JIT):** A system where a customer initiates demand, and the demand is then transmitted backward from the final assembly all the way to raw material, thus ''pulling'' all requirements just when they are required.
- **Kanban:** A signalling system for implementing JIT production.
- **Total preventive maintenance (TPM):** Workers carry out regular equipment maintenance to detect any anomalies. The focus is changed from fixing breakdowns to preventing them. Since operators are the closest to the machines, they are included in maintenance and monitoring activities in order to prevent and provide warning of malfunctions.
- **Setup Time Reduction:** Continuously try to reduce the setup time on a machine.
- **Total Quality Management (TQM):** A system of continuous improvement employing participative management that is centred on the needs of customers. Key components are employee involvement and training, problem-solving teams, statistical methods, long-term goals, and recognition that inefficiencies are produced by the system, not people.
- **5S:** Focuses on effective work place organization and standardized work procedures.

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- **Total Productive Maintenance:** The lean paradigm has developed as a holistic approach to manufacture and business. To support the implementation of lean principles, increasingly holistic approaches to mapping and evaluating the supply chain have been developed [6].

3. Value Stream Mapping

VSM was formed from Toyota production system and lean manufacturing principles [2]. It was originally called "material and information flow maps"[6]. Rother and Shook (1999) rightly argue that whenever there is a product for a customer, there is a value stream.

Value Stream Maps identify ways to get material and information to flow without interruption, improve productivity and competitiveness, and help people implement system rather than isolated process improvements. They have been applied to manufacturing activities, office activities, healthcare, education and government services. Value added time percentage is the key metric of the mapping – comparing value adding (VA) with non-value adding (NVA) activity [4].VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream [7].

3.1 Five Phases of Value Stream mapping

As regards the application process, VSM is based on five phases put into practice by a special team created for such a purpose [6]. The phases are:

1. Selection of a product family;
2. Current state mapping;
3. Future state mapping;
4. Defining a working plan; and
5. Achieving the working plan

There are two types of value-stream maps: "Current state," and "future state," As the name implies, "current-state" value-stream maps depict the present way in which material and information are processed. "Future-state" value-stream maps depict a future condition that incorporates yet-to-be-made improvements.

3.2 Guidelines For Value Stream Mapping

Guidelines are needed for the definition of the future state map; lean thinking provides them to assist users in how this map should be drawn [6][8][9]. These guidelines are summarized below:

- The production rate must be imposed by the product demand. Takt time is the concept that reflects such a rate.
- Establishment of continuous flow where possible (unique product transfer batches).
- Employment of pull systems between different work centres when continuous flow is not possible.
- Only one process, called the pacemaker process, should command the production of the different parts. This process will set the pace for the entire value stream. Downstream this point the items would flow in a First In First Out (FIFO) sequence; upstream, the production will be triggered by pull signals.
- Pacemaker process scheduling will deal with the maximization of production levelling on mix and volume.
- Improvement of the overall process efficiency. Projects such as work methods and cycle time improvements, changeover time reductions and maintenance management could be launched by the VSM team.

Types of Processes in Value Stream Mapping

In an internal manufacturing context, there are three types of operation that are undertaken [4]

(1) Non Value Adding (NVA)
(2) Necessary but non value adding (NNVA)
(3) Value adding (VA)

Non Value Adding activities involve pure waste and must be eliminated completely. Necessary but non-value adding operations include those activities which may be wasteful but necessary under the current operating procedures. It would require major changes in the operating system to eliminate these types of operation. Value Adding Activities constitutes of those processes for which the customer is willing to pay.

3.3 Seven Types of Wastes In Value Stream Mapping

There are seven commonly accepted wastes in the Toyota production system (TPS) [10]:

1. Overproduction: Producing too much or ahead of demand, resulting in poor flow of information or goods and excess inventory.
2. Waiting: Long periods of inactivity for people, information or good due to delay from the previous processing steps, resulting in poor flow and long lead-times.
3. Transport: Excessive movement of people, information or goods, resulting in wasted time and cost.
4. 4. Inappropriate processing: Going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach may be more effective.
5. Unnecessary inventory: Excessive storage and delay of products, resulting in excess inventory and costs, leading to poor customer service
6. Unnecessary motion: Poor workplace organization, resulting in poor ergonomics, e.g., unwanted movement of the workers and frequently lost items.
7. Defects: Frequent errors in paperwork or material/ product quality problems resulting in scrap and/or rework, as well as poor delivery performance.

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 [6].

3.4 Limitations of Value Stream Mapping

Problems or difficulties identified while using VSM [11]-

Those specifically associated with the value stream mapping method

1) There are a range of other wastes that were found in a supply chain setting such as wasted energy (lighting, heating) and the waste of human potential when human resources are under-used.
2) The seven tools do not cover every eventuality and are weaker in some circumstances such as in mapping information flow. It was felt that often lower tools could be employed on occasion as required. The

method does not explicitly allow this including shop-floor downtime analysis.

3) The method's concentration on value streams or those linked activities that went towards producing a single or closely linked group of products and services displayed a weakness where value streams met.
4) A lack of understanding on how the method moves from mapping outcomes to the "chocolate box" and the final implementation approach.

4. Current State Description

This paper has used a case-study based approach to demonstrate that how Value Stream Mapping can help industries to eliminate waste, maintain better inventory and have an overall better control of the operations management.

Production Layout

The production control sends a one month forecast to the steel supplier and takes delivery on a weekly basis. The final product is also shipped out to the market on a weekly basis. The mode of transportation is via truck.

The production control receives 4 types of demands- 3 months order, 30 day order, weekly order, spot business. The zigzag arrows represent electronic information flow.

The company produces 3 different grades of steel -

1. Open Coil Annealed (Demand – 8500 tons per month)
2. Continuous Annealed (Demand – 10,000 tons per month)
3. Hydrogen Batch Annealed (Demand – 58,000 tons per month)

The various stages undergone to produce this product family are as follows:

1. Blast Furnace: Iron Ore, Lumps/ Sinter/ Pellet and coke are fed in blast furnace from top whereas heated and pressurized air is blown from below to trigger a series of reactions through which iron is extracted from iron ore in hot molten state, called as Hot Metal.
   No. of workers required is 30. The cycle time 8100 seconds with an uptime of 85%. The inventory level is 1384 units. The waiting time for the next process to begin is 0.54 days.
2. Basic Oxygen Process (BOP): Hot Metal or Liquid Iron contains about 4% Carbon and other impurities. In this stage, iron is converted into steel by reducing its carbon content and other impurities in the Basic Oxygen Furnace.
   No. of workers required is 12. The cycle time 2700 seconds with an uptime of 90%. The inventory level is 2707 units. The waiting time for the next process to begin is 0.2 days.
3. The liquid steel is then sent either to a Ladle Metallurgical facility (LMF) or a Degasser to further refine and remove impurities as per the grade of the final steel to be produced. The refined liquid steel then goes to a dual-strand continuous caster where steel slabs are cast in accordance with specific customer widths.
   No. of workers required is 4. The cycle time 2400 seconds with an uptime of 100%. The inventory level is 50 units. The waiting time for the next process to begin is 0.29 days.
4. Continuous Casting: The liquid steel obtained from Ladle Metallurgical facility (LMF)/ Degasser is cast in different shapes and sizes depending on the type of finished product to be made.
   No. of workers required is 30. The cycle time 2700 seconds with an uptime of 90%. The inventory level is 26385 units. The waiting time for the next process to begin is 10.33 days.
   The hot slabs are then transported on railroad and rack cars from the continuous caster process to the finishing mill facility for further refining processes, which include the hot strip mill (HSM), pickling, cold reduction (CR), annealing , temper mill and finally, shipping.
5. Hot Strip Mill (HSM): The Hot Strip Mill is where the rolling operations begin, as steel slab is reheated and rolled to hot rolled coil. Different type of rolling mills tailor make steel products in terms of size, shape and property as per customer requirement.
   No. of workers required is 18. The cycle time 9000 seconds with an uptime of 85%. The inventory level is 45000 units. The waiting time for the next process to begin is 17.65 days.
6. Pickling: is used to remove impurities, such as stains, inorganic contaminants, rust or scale from the steel slab. A solution called pickle liquor, which contains strong acids, is used to remove the surface impurities.
   No. of workers required is 16. The cycle time 240 seconds with an uptime of 100%. The inventory level is 10000 units. The waiting time for the next process to begin is 3.9 days.
7. Cold Reduction: The steel slab is rolled again at a temperature below its recrystallisation temperature.
   No. of workers required is 30. The cycle time 420 seconds with an uptime of 85%. The inventory level is 2600 units. The waiting time for the next process to begin is 9.04 days.
8. Annealing: involves heating the steel slab to above its glass transition temperature, maintaining a suitable temperature, and then cooling. Annealing induces ductility, softens the steel, relieves internal stresses, refines the structure by making it homogeneous, and improves cold working properties.
   No. of workers required is 16. The cycle time 1050 seconds with an uptime of 100%. The inventory level is 10344 units. The waiting time for the next process to begin is 3.64 days.
9. Temper Mill: is a steel sheet or steel plate processing line composed of a horizontal pass cold rolling mill stand, entry and exit conveyor tables and upstream and downstream equipment depending on the design and nature of the processing system. The primary purpose of a temper mill is to improve the surface finish on steel products.
   No. of workers required is 13. The cycle time 420 seconds with an uptime of 100%. The inventory level is 1384 units.
10. Shipping: The rolled and packaged finished product is dispatched to end customer from here. No. of workers required is 39.

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4. VSM Application - Current State Map for Case

The various steps involved in designing a current state map are as follows [12] [13]:

1. The icons for the supplier, customer and the production control are drawn.
2. A data box showing the demands of the customer is drawn right below the customer icon.
3. The mode of transportation is shown with a suitable icon with arrow directions to show the movement of goods between the supplier, the shop and the customer. The frequency of the deliveries is shown in a data box right next to the truck icon.
4. The different processes are now listed along with the number of workers that are operating on that process. The Cycle time, Change Over time, Available time, Up time and actual Value Added time are now calculated and listed in data boxes right below the corresponding processes.
5. The information flow between the production control, operators, supplier and the customer are indicated along with their frequency.
6. The push-pull and FIFO strategies are then drawn. This concludes the Current State Map.

5. Value Stream Mapping Symbols

Commonly used symbols in Value Stream Mapping are shown in figure 1. After using these symbols, Current State Map is shown in figure 2.

Operations Symbols

- Process
- U-cell
- Operator
- Factory
- Production Control
- Schedule
- Go See
- Fifo Lane
- Kaizen Burst
- Shipment Arrow
- Push Arrow
- Manual Information Arrow
- Electronic Information

Timelines and Data Table formatting

- Non - Value Added time
- Value Added time
- Timeline tool
- Data table

Inventory Symbols

- Production Kanban
- Batch production Kanban
- Withdrawal Kanban
- Batch Withdrawal Kanban
- Supermarket
- Buffer
- Inventory
- Signal Kanban
- Kanban Post
- Physical Pull
- Sequence Pull
- Pull Arrow 1
- Pull Arrow 2
- Pull Arrow 3
- Pull Arrow 4

Material Movement Symbols

- Truck
- Forklift
- Air-plane
- Boat

Fig: 1. Symbols used in VSM

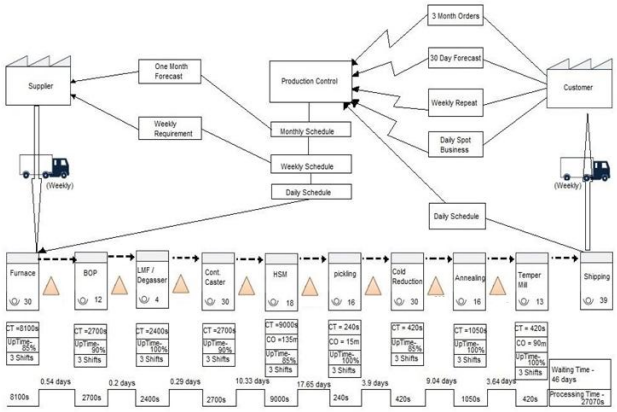

Fig: 2- Current State Map

6. Conclusions

From the above it is concluded that the total waiting time is 0.5486 days and the value added time is 27030s = 0.3128 days. Thus the value added time is about 57% of the total waiting time. Thetakt time is calculated by dividing the total production rate by the customer demand. Assuming 30 days per month, the takt time becomes 76,500 tonnes/30 = 2550 tonnes/day. Average coil weight is 20 tonnes therefore 2550/20 = 127 coils/day. The company runs for 24 hours every day thus 1440/127 = 11.3 min. per coil. Thetakt time is calculated to be 11.3 minutes.

The problems associated with the current state processes are –

- Huge Inventory before each process
- Value added time is very less compared to the total production time.

The performance of the steel plant may be improved through following measures [5]:

After analysing current state map, future state map can be made to improve the performance of this production system.

Major recommendations are as follows.

1. Introduction of Supermarket at the following areas –
   - Pickling
   - Cold Reduction
   - Annealing
   - Temper Mill
   - Shipping

The supermarkets are not introduced in the earlier stages of processing as they are continuous processes whereas in the finishing end, a large number of inventory exists.

2. Introduction of a Kanban-Pull system for the supermarkets. This would mean that a coil would be produced only when there is an empty coil slot in the supermarket. This would result in zero overproduction of the coils. The push-pull boundary is between Hot Strip Mill and Temper Mill [14][15].
3. Introduction of a Pacemaker process at the Temper Mill.
4. Introduction of a Batch Production system at the pacemaker. This will prevent long lead-times, Work in Process inventory, finished goods inventory and Overproduction.
5. Withdrawal of the finished goods at the temper mill according to the pitch.
6. Introduction of Total Productive Maintenance (TPM) at the Blast furnace, BOP, Degasser, Hot Strip Mill, Pickling, Cold Reduction and Temper Mill. TPM can reduce the lead time, inventory and increase Overall Equipment Effectiveness (OEE).
7. Introduction of Single Minute Exchange of Dies (SMED) at the Continuous Caster, Hot Strip Mill, Pickling, Cold Reduction and Temper Mill.
8. Introduction of 5S at Hot Strip Mill and Shipping.

Therefore this study implies that VSM is very important tool to identify major waste and thereby improving overall performance of organisations.

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