

Implementation of Lean in Automotive Component Manufacturing Process

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Abstract - Lean manufacturing appears to hold considerable promise for addressing a range of simultaneous, competitive demands including high levels of process and product quality, low cost and reductions in lead times. This addresses the application of lean manufacturing concepts to the continuous production sector with a focus on the Automotive Component manufacturing industry. The goal of this is to investigate how lean manufacturing tools can be adapted from the discrete to the continuous manufacturing environment. This paper presents lean manufacturing as a leading manufacturing paradigm applied in many sectors. The fundamental focus on lean production is the systematic elimination of non-value added activity and waste from the production process. The implementation of lean principles and methods results in improved system and surrounding performance. Value stream mapping is used to first map the current state used to identify sources of waste and to identify lean tools to eliminate this waste. The future state map is then developed for a system with lean tools applied to it. To quantify the benefits gained from using lean tools and techniques in the value stream mapping, a detailed simulation model is developed and a designed experiment is used to analyze the outputs of the simulation model for different lean configurations. This paper demonstrates the implementation of lean philosophy through layout modification.

Improve productivity and increase profits through lean manufacturing.

The ultimate goal of lean manufacturing is to reduce waste in manpower, inventory, time to market, to become highly responsive to customer demand while producing quality products in a more efficient and economical manner [11]. It is well known that seven types of waste generally occur [9] as listed in Table 1.

TABLE I: SEVEN TYPES OF WASTES

Waste	Description
Over production	Producing too much or too soon, resulting in poor flow of information or products
Unnecessary inventory	Excessive storage and delay of information or products, resulting in excess inventory, leading to a high holding cost and poor customer service
Waiting	Long periods of inactivity of people, information or products, resulting in poor flow and long lead times
Excessive transportation	Excessive movement of people, information or products, resulting in wasted time and cost
Defects	Frequent errors in paperwork, material, final product quality problems, resulting in scrap and/or rework, as well as poor delivery performance
Ineffective Motion	Process is not well designed so that the operator will waste much more time for excess motions to handle the process
Inappropriate processing	Process itself is inappropriate caused by using the wrong set of tools, procedures or systems

Key Words: Lean Manufacturing, Value Stream Mapping, VSM, Bottleneck, Line balancing

1. INTRODUCTION

As the demand for new product requirement in the modern automotive field is increasing day-by-day with latest technology up gradation like noiseless motion (EPA noise requirements), friction free conversion of power transmission and capable of transmitting load and speed is drastically increasing to compete with the world leaders.

Our Scope is concerned with manufacturing of inverted tooth chains. To implement a methodology in manufacturing of Inverted toothed chains so as to enhance current customer's demand of 0.65Lakh units/month and to extract new customers with customer delight as our quality policy.

Visualizing the flow creates the ability to see where, when, and how both the information and product flows through, and consequently recognize and eliminate the source of waste. Unfortunately, many manufacturers have failed to fully understand this in their initial excitement and eagerness to start with the lean approaches. The implementation of these approaches involves more than just applying individual concepts like Kanban, layout planning, visual control, and takt time calculations [1]. Typically, such organizations sporadically carry out these activities without linking their efforts to a systematic framework.

A critical assessment of many lean tools suggests that a key weakness is the absence of a visual nature, i.e., the ability of people with knowledge of lean techniques to explain the current dynamics of the organization and to communicate an action plan that would be understood by all key stakeholders. There is a need to develop a more systematic means to help guide these lean tools and activities. Value stream mapping (VSM) is vigorously capable of undertaking this role. It not only highlights process inefficiencies, Transactional and communication mismatches, but also guides the improvement area.

2. LITERATURE SURVEY

The concepts required for the project were gathered and studied from various journals published in the field of lean manufacturing techniques, for improving productivity and quality.

2.1 Lean

The new uprising in the manufacturing goods and service sector has created great challenges for the industries. Customer driven and highly competitive market has rendered the old method of managerial approach is inadequate to cope with these challenges. These factors formed a big challenge for companies to look for new tools to move up the ladder in a global competitive growing market. To become more profitable many manufacturers have started to turn into lean manufacturing principles to elevate their performance.

The basic idea behind a lean manufacturing system, which has been practiced for many years in Japan, are waste elimination, cost reduction and employee empowerment. The Japanese philosophy of doing business is totally different than that of the US. The traditional belief in the west is that, the only way to make profit is to add it to the manufacturing cost in order to come up with a desired selling price [7]. On the contrary, Japanese believes that customers are generated of the selling price. The more quality one is built into the product and more service one offers, the more the price customers will pay.

The lean manufacturing discipline is to work in every facet of value stream by eliminating waste in order to reduce costs,

generate capital, and bring in more sales in order to be competitive in a growing global market.

The term lean as Womack defines it denotes a system it utilize less inputs, to create the same output created by the traditional mass production system, with increase product variety[8]. This business philosophy goes by different names, Agile manufacturing, just in time manufacturing, synchronous manufacturing, world class manufacturing and continuous flow are the terms used parallel with lean manufacturing.

Lean focuses on abolishing or reducing wastes (or “muda”, the Japanese word for waste) and on maximizing or fully utilizing activities that add value from the customer’s perspective. From customer’s perspective, value is equivalent to anything that the customer is willing to pay for product or service that follows. So elimination of waste is the basic principle of lean manufacturing. For companies this would involve any of these following [7],[10],[11].

- Material: Convert all raw materials to end products. Avoid excess raw materials and scrap.
- Inventory: Keep Constant flow to the customer and to have idle material.
- Overproduction: Produce the exact quantity as per customers demand, and when they need it.
- Labour: Get rid of unwanted footprints.
- Complexity: Try to solve problems in an uncomplicated way rather than complex way.
- Energy: Maximize the utilization of equipment and people in most productive way. Avoid unnecessary operations and excess power utilization.
- Space: Reorganize equipment, people and workstations to get a better space.
- Defects: Make every effort to eliminate waste.
- Transportation: Get rid of transportation of information and material that does not add value to the product.
- Time: Avoid long setups, delays and unexpected machine downtime.
- Unnecessary Motion: Avoid excessive bending or stretching and frequently lost items.

The most significant source of waste is inventory. Work-in-process and finished goods inventory does not add value to the product and they should be reduced or eliminated. When inventory is reduced, hidden problems can appear and actions can be taken immediately. There are many ways to reduce the amount of inventory, one of which is reducing lot size. Lot size can be reduced by reducing the set up time, so as to make the cost per unit constant as the economic order quantity formula states [4].

At Toyota Shingo developed the concept of single minute exchange of die (SMED) to reduce the set up time [10]. For instance, set up time in punching presses can be reduced from hours to less than ten minutes. Another method to reduce inventory is by minimizing machine down time, this can be achieved through Preventive maintenance.

Transportation time is another source of waste. Moving parts from one end of the facility to another involves time, energy and people; this can be minimized by utilizing cellular layout or U-shaped Assembly lines to ensure continuous flow of production. Another source of waste is defected and scrap. Total productivity maintenance is one way to eliminate defects and scrap. Manufacturing parts that are fault-free from the beginning has profound consequences for productivity [3].

There is no doubt that elimination of waste is an essential ingredient for survival in today's growing market. Companies must strive to create high-quality, and low cost products that can get to the customers in the shortest time possible. There are sets of tools that were developed at Toyota and that can be utilized to eliminate or at least reduce the source of waste.

2.2 Lean Manufacturing Tools and Techniques

Once companies identify the major sources of waste, tools such as continuous improvement, just-in-time production, production smoothing and others will guide the company to eliminate the waste.

2.2.1 Cellular Manufacturing: Cellular manufacturing is a concept that increases the mix of the products with minimum waste. A cell consists of equipment and workstations that are arranged in an order that maintains a smooth and continuous flow of materials and components through the process. It also has operators well trained to operate in that cell.

One of the advantages of cell is one-piece flow concept, which states that each product moves through process one unit at a time without sudden interruption, as per the demand of the customers. Extending the product mix is another advantage of cellular manufacturing. When customers demand a high variety of products as well as faster delivery rates, it is important to have flexibility in the process to accommodate their needs. This flexibility can be achieved through grouping similar products into families that can be processed on the same equipment in the same sequence. This will also shorten the time required for change over between products. Other benefits include:

- Improved productivity and Better space utilization
- Enhanced flexibility and visibility
- Inventory reduction (WIP) and Lead time reduction
- Reduced Transport and material handling.
- Identification of causes of defects

2.2.2 Continuous Improvement: Continuous improvement is another fundamental principle of lean manufacturing. Kaizen, which is the Japanese word for a continuous endeavour for perfection. Kaizen is a systematic approach to gradual, orderly, continuous improvement. In manufacturing settings improvement can take place in many forms such as reduction of inventory, reduction of defective parts. One of the effective continuous improvement tools is 5S.

5S is a first, modular step toward serious waste reduction. 5S consists of the Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and clean), Seiketsu (Systemize), and Shitsuke (Standardize). The underlying concept is to look for waste and try to eliminate it. Waste could be in the form of scrap, defects, raw materials, unneeded items, old broken tools, and obsolete jigs and fixtures.

2.2.3 Just-in-Time: It is a management idea that attempts to eliminate the sources of manufacturing waste by producing the right part in right place and at the right time. This addresses the waste such as work-in-process material, defects, and poor scheduling of parts delivered. [6]. Inventory and material flow systems are typically classified as either push (traditional) or pull (just-in-time) system. Customer demand is the driving force behind both systems. However the major difference is in how each system handles customer demand. Just-in-time is a tool that enables the internal process of a company to adapt to sudden changes in the demand pattern by producing the right product at the right time and in right quantities. Moreover, just-in-time is a critical tool to manage the external activities of a company such as purchasing and distribution.

Benefits of JIT are [6].

- Eliminating unnecessary work-in-process, this results in reduction of inventory cost.
- Since units are produced only when required, quality problem can be detected early.
- Since inventory is reduced, the waste of storage place will be reduced.
- Preventing excess production can uncover hidden problems.

2.2.4 Production Smoothing: In lean manufacturing system it is important to move to a higher degree of process control in order to strive to reduce waste. Another tool to accomplish this is production smoothing. Heijunka, the Japanese word for production smoothing, is where the manufacturers try to keep the production level as constant as possible from day to day [11]. Heijunka is a concept adapted from the Toyota production system, where in order to decrease production cost it was necessary to build no more cars and parts than the number that could be sold. To accomplish this, the production schedule should be smooth so as to effectively produce the right quantity of parts and efficiently utilize man power. If the

production level is not constant this will lead to waste (Work-in-process inventory) at the workplace.

2.2.5 Standardization of work: A very important principle of waste elimination is the standardization of work actions. Standardized work basically ensures that each job is organized and is carried out in the most effective manner, no matter who is performing the job, the same level of quality to be achieved. At Toyota every worker follows the same processing steps all the time needed to finish a job, order of steps to follow the job and parts on hand. By doing this one ensures that the line is balanced, unwanted work-in-process inventory is minimized and non-value added activities are reduced. A tool that is used to standardize work is called “takt” time. Takt (German for rhythm or beat) time refers to how often a part should be produced in a product family based on the actual customer demand. The target is to produce at a pace not higher than the takt time (Mid-America Manufacturing Technology Centre press release, 2000). Takt time is calculated based on the following formula [2].

$$\text{Takt Time} = \frac{\text{Available Work Time per day in sec}}{\text{Customer Demand per day}}$$

2.2.6 Other Waste Reduction Techniques: Some of the other waste reduction tools include zero defects, setup reduction, and line balancing. The goal of zero defects is to ensure that the products are fault-free all the way, through continuous improvement of the manufacturing process [4]. Human beings almost invariably will make errors. When errors are made and are not caught, then defective parts will appear at the end of the process. However, if errors can be prevented before they happen then defective parts can be avoided. One of the tools that the zero-defect principle uses is poka-yoke. Poka-yoke, which was developed by Shingo, is an autonomous defect control system that is put on a machine that inspects all parts to make sure that there are zero defects. The goal of poka-yoke is to observe the defective parts at the source, detect the cause of the defect, and to avoid moving the defective part to the next workstation [2].

3. Objective

The objective of our project is to demonstrate systematically how lean manufacturing tools used appropriately so that industry can eliminate waste. Hence better inventory control, better product quality, and better overall financial and operational procedure can be achieved. To study of opportunities for continuous improvement (KAIZEN) in an assembly line. From the fig.1 is to explain the Objective of lean implementation.

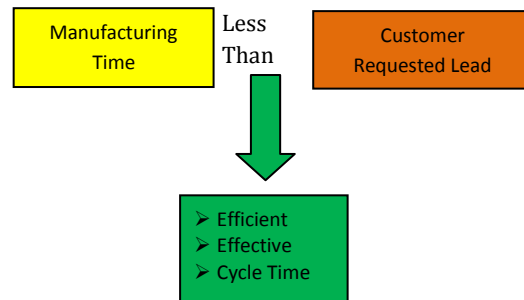


Fig. 1 Objective Flowchart

4. METHODOLOGY

Getting started with an effective program to implement lean manufacturing requires careful planning, design and execution of the business changes needed to achieve the desired improvement goals. Implementation should not begin unless top management is solidly championing the effort with an understanding that many business processes must be changed. Starting with a pilot product line or other contained area of the business is a big help to “proof” your concept and methodology. Organize and plan for Lean manufacturing with executive champion.

- Conduct extensive education
- Value stream map administrative, engineering and production processes.
- Develop concept for lean manufacturing pilot
- Establish improvement targets
- Develop time-phased implementation Plan
- Present lean manufacturing pilot concept and plan to management
- Obtain management approval and commitment
- Train all employees involved in pilot

The implementation of lean concept is a step by step process. Implementation steps are explained in the flowchart as shown in the Fig 2. Current state process of assembly layout in an automotive component manufacturing company is analysed and current state value stream mapping is plotted (drawn). With the help of VSM bottleneck operations at machines and the nature of wastes (transportation time, distance, and work in process) are identified using calculations. Wastage type is identified and evaluated. A new layout model is developed using VIP planopt.

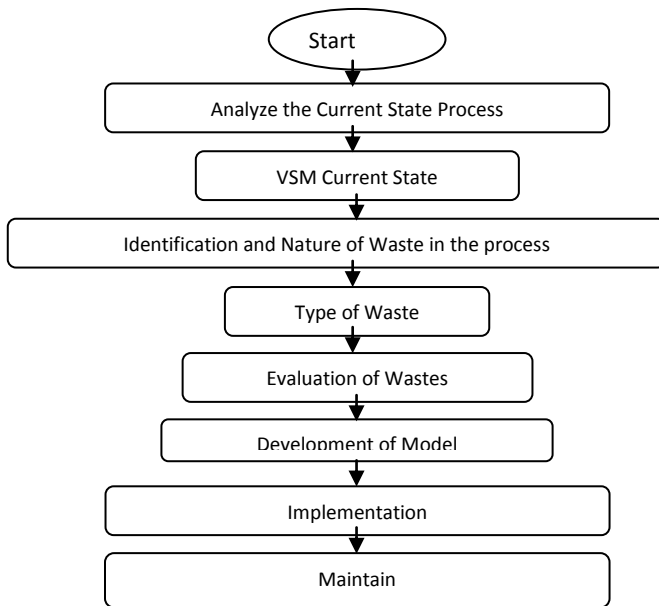


Fig. 2: Methodology Flowchart

4.1 Major Clients

Major clients include Original Equipment Manufacturers like

- Harley Davidson
- Polaris
- Honda
- TVS
- Cannon etc.,

4.2 Product description

Inverted tooth chain as shown in the Fig 3 with single pin joints. Virtual silent chain with excellent wear resistance. The meshing of the toothed links with the sprocket gives this chain optimum acoustic property for timing drives where acoustics are crucial, especially for petrol engines. The low weight of the 6.35 mm pitch makes it ideal for downsizing timing drives with moderate loads.



Fig. 3 Inverted Tooth Chain

4.3 Problem Definition

As the existing Manufacturing process sets up unable to meet the current demand, also change over time is drastically high. Existence of variation (approx 2% reduction)

in the products affecting the product performance, making the way for the competitors to intrude into the market.

4.4 Selection of Critical Shop Floor

The first step in this methodology is a selection of the critical Shop floor. All the production environments were studied. Assembly shop was reflecting the number of defects and was not meeting the customer demands. So the assembly shop floor was selected as the critical shop floor.

5. VALUE STREAM MAPPING

A value stream is a collection of all action's 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, from raw material to the arms of the customers. These actions are those in the overall supply chain, including both information and operation flow, which are the core of any successful lean operation. Value stream mapping is an enterprise improvement tool to assist in visualizing the entire production process, representing both material and information flow.

The goal is to identify all types of waste in the value stream and take steps to try and eliminate them. Taking the value stream viewpoint means working on the big picture and not individual processes, and improving the whole flow and not just optimizing the pieces.

A manufacturing system operates with timing of step-by-step activities. The various steps in implementation of VSM are shown in Fig 4 and are discussed in the following sections. The analysis process is carried out by collecting the data from various inquiries with expertise in shop floor, workers and directly participating in measuring the time of various processes.

5.1 Preparation of Current State Map

Interaction with the industry the information on the customer requirement. The VSM input data are arriving as shown in Table II. The company has a wide range of customer request for a wide range of product as listed in Table III. Customer requirement of 65000 pieces /month.

TABLE II : VSM INPUT DATA

Customer Order	65000 Pieces / Month
Demand	2500 pieces / Day
Working Hours	3Shifts 8Hours / Shift
Break	45 min/ Shift
Raw Materials	Every 3Days

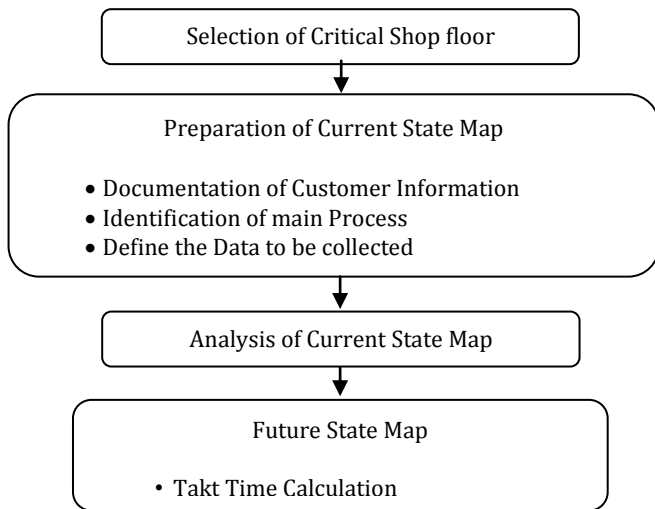


Fig. 4: VSM Implementation Flowchart

TABLE III: PRODUCT DETAILS

Product Type	Number of Pitches	Centre Distance (mm)
INVA	90	177.799
	92	184.149
	94	190.5
	96	196.85
	100	209.549
INVB	94	196.85
	110	247.649
	118	273.05
INVC	118	241.299
INVD	180	419.099
INVE	66	136.525

5.1.1 Identification of Main Processes:

Quick walk through the shop floor (gemba) helps to identify the main process. The main processes involved in assembly shop floor are shown in Fig 5.

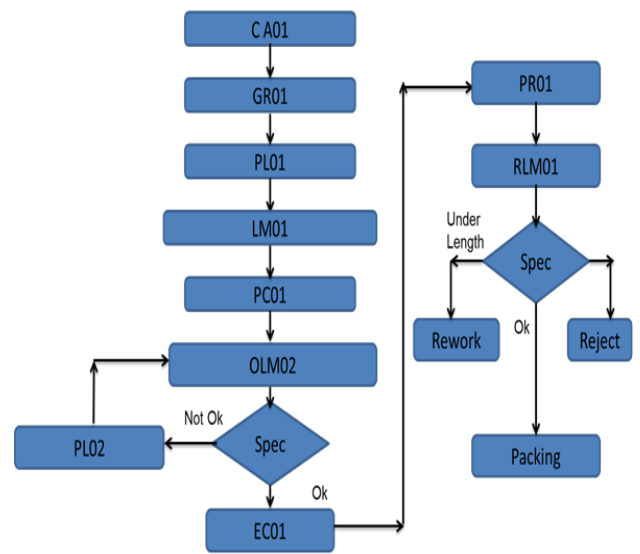


Fig. 5: Current Process

5.1.2 Define the Data to be collected: The data in the data box serve to track down the opportunity for improving the collection of appropriate data benefits in quick tracking of the opportunities. The data box envelopes the following data like cycle time, change over time, uptime and available time. The inventory triangle envelopes, two data, work in process between each process and respective inventory.

5.1.3 Process Cycle Observation: Process cycle time is observed and bottle Neck Process is Identified as shown in Table IV.

TABLE IV: PROCESS CYCLE TIME

S.No	Process	Cycle time in Sec
1	CA01 Machine	38
2	GR01 Machine	54
3	PL01 Machine	152
4	PC01 Machine	5
5	OLM02 Machine	10
6	PL02 Machine	18
7	MEC Machine	36
8	PR01 Machine	120
9	RLM Machine	10
10	Packing	30

5.1.4 Current Facility: Current Facility with 5 Assembly Lines and 34 Operators in achieving the demand as shown in Table V.

TABLE V: CURRENT FACILITY

Description	Assembly Line	OLM02	PL02	PR01	RLM
Machine	5	5	5	6	4
Man Power	5	5	5	15	4

5.2 TAKT Time: A Benchmark for Process Pace

Takt demonstrates the rate at which the customer buys the product. TAKT reflects the frequency at which the product has to come out of the manufacturer to meet the customer demand. Takt time is calculated by dividing available working time per day (in sec) with the customer demand per day.

$$Takt\ Time = \frac{Available\ Work\ Time\ per\ day\ in\ sec}{Customer\ Demand\ per\ day}$$

$$Takt\ Time = \frac{78300}{2500}$$

Takt Time = 31.3 sec

Demand = 65000 pieces / month

Demand = 2500 pieces / month

TAKT Time of 31 seconds represents, every piece has to be completed in every 31 seconds. The current state map sights as shown in Fig. 7, that GR01, PL01, MEC and PR01 processes takes more time than the Takt time and Work Balancing as shown in Fig. 6 and Table VI. In order to address the problem layout modification was carried out.

5.3 Process Improvement

Improvements in quality, flexibility and speed are commonly required. The following lists some of the ways that processes can be improved.

- Rearranging the layout to eliminate large amounts of inventory between operations
- Combining of Process, so as to eliminate post assembly processing and validation as shown in Fig. 8
- To improve the efficiency of the bottleneck activity as shown in Fig.9
- Minimize non-value adding activities (reduce lead time)
- Eliminating the batching and moving to one piece flow

TABLE VI: WORK BALANCING

S No	Process	Cycle Time (sec)	Value Added Time (sec)	Non-Value Added Time (sec)
1	CA01 Mc.	38	38	
2	G R01 Mc.	54	54	
3	PL 01 Mc.	152	32	120
4	PC 01 Mc.	5	5	
5	OLM 02 Mc.	10	10	
6	PL 02 Mc.	18	18	
7	MEC Mc.	36	36	
8	P R 01 Mc	120	15	105
9	R LM Mc	10	10	
10	Packing	30	30	

Work Time = 248 sec

Takt Time = 31 sec

$$\# \text{ of Operators Required} = \frac{Work\ Time}{Takt\ Time}$$

= 8 Operators

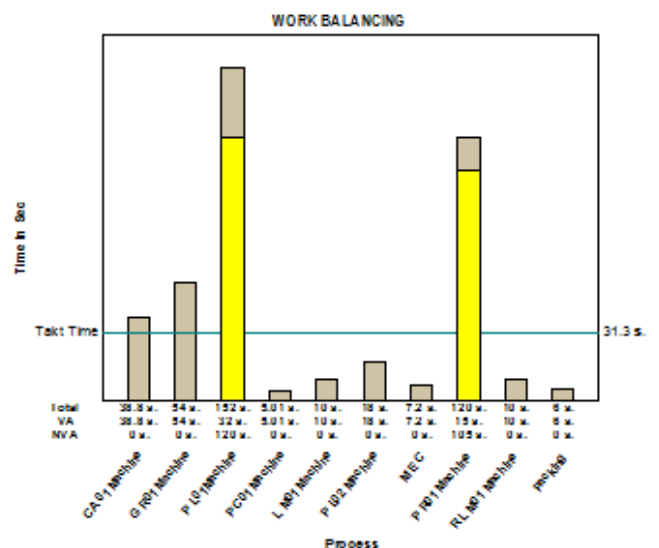


Fig. 6: Work Balancing

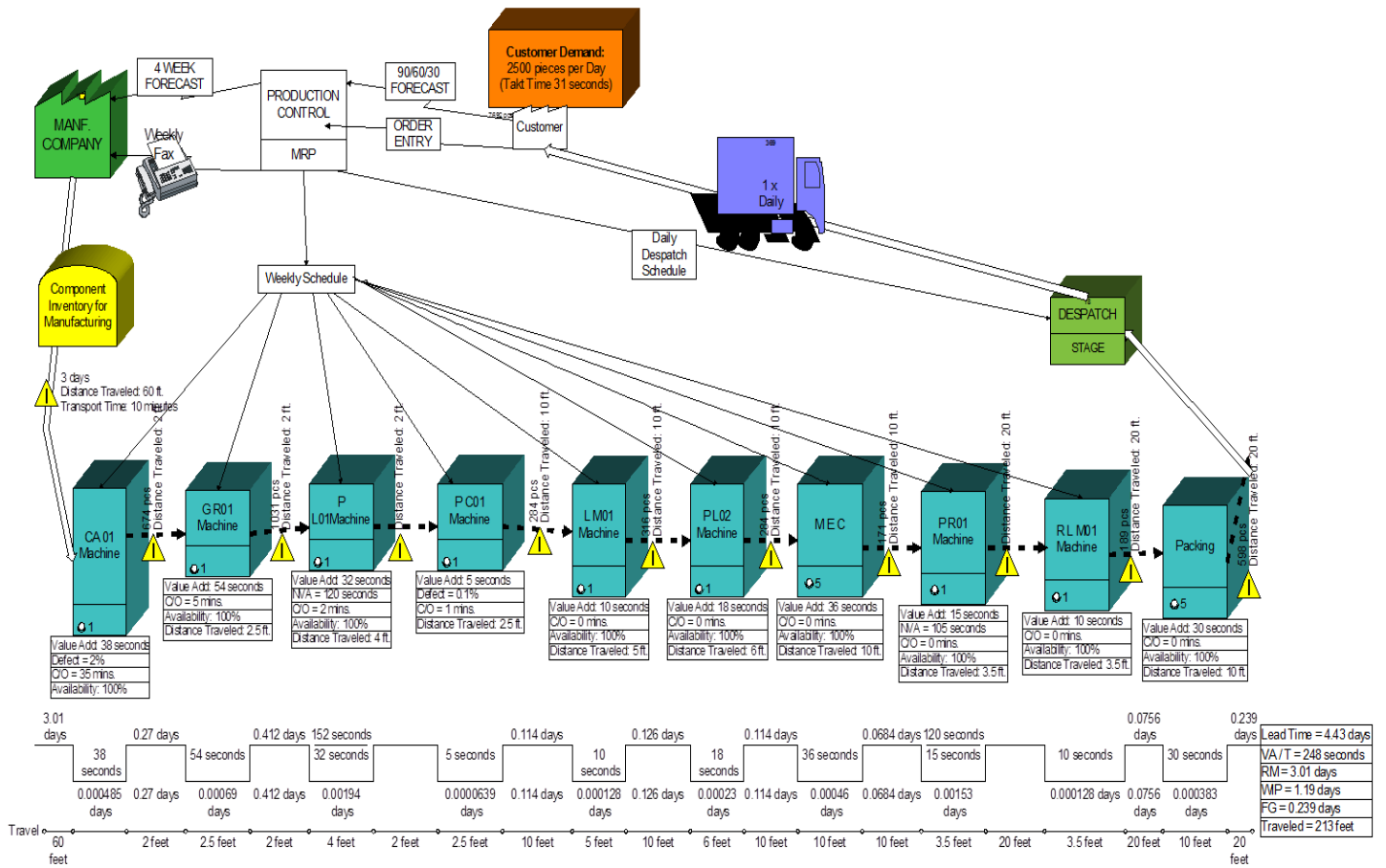


Fig. 7: Current State

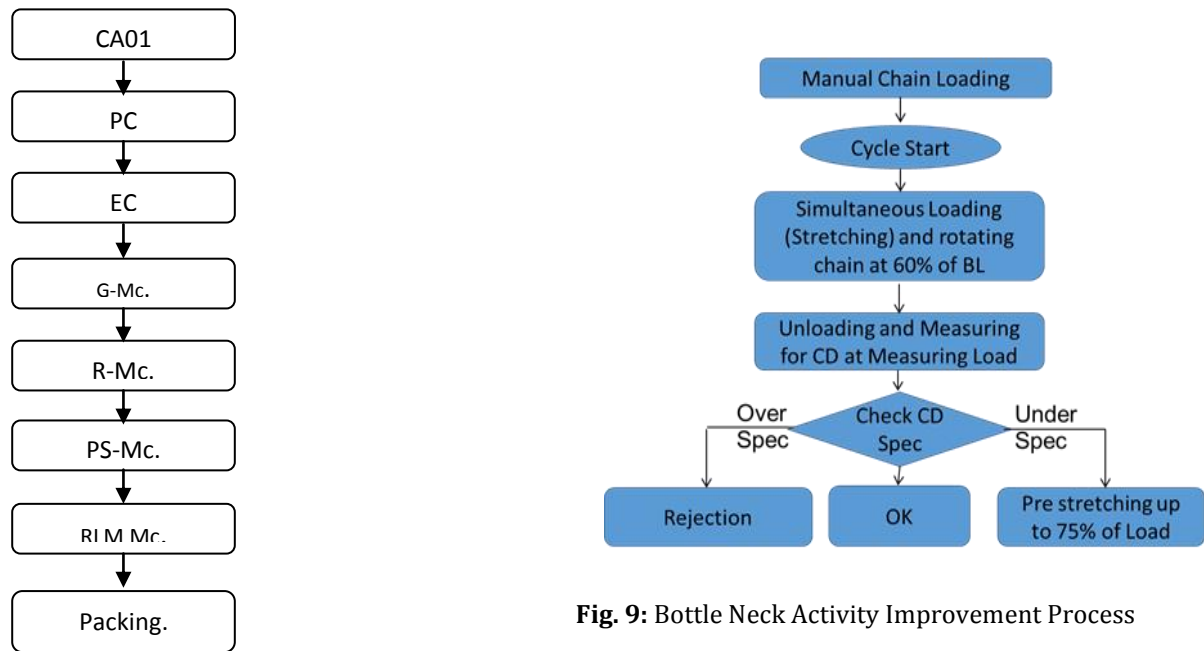


Fig. 8: Lean Method Process Sequence

Fig. 9: Bottle Neck Activity Improvement Process

5.4 Cycle Time Observation

5.4.1 Future State -1: After Process Improvement, Cycle time is observed as shown in Table VII. As in the table R-Machine time is more than the Takt time, still improvement can be made. VSM for future state 1 is drawn as shown in Fig. 10, Work Balancing is calculated as shown in Table VII and Fig.11

Table VII: Cycle Time Observation

S.No	Process	SPM	No Of Pins / min	Cycle time Sec
1	C A01 Machine	90	270	22
2	PC Machine	80		10
3	EC Machine	80		12
4	G- Machine	130	260	25
5	R-Machine	130	130	48
6	PS- Machine			18
7	R LM Machine			10
8	Packing			30
				175

TABLE VIII: WORK BALANCING

S No	Process	Cycle Time (sec)	Value Added Time (sec)	Non-Value Added Time (sec)
1	CA01 Machine	22	22	
2	PC Machine	10	10	
3	EC Machine	12	10	2
4	G- Machine	25	22	3
5	R-Machine	48	46	2
6	PS- Machine	18	18	
7	R LM Machine	10	10	
8	Packing	30	30	
			168	

Work Time =168 sec

Takt Time = 31 sec

$$\# \text{ of Operators Required} = \frac{\text{Work Time}}{\text{Takt Time}}$$

= 6 Operators

5.4.2 Future State -2: As in the table R-Machine time is more than the Takt time, still improvement can be made. So Twin Station was introduced and cycle time was observed as shown in Table IX. VSM for future state-2 is drawn as shown in Fig.13, Work Balancing is calculated as shown in Table X and Fig 12

TABLE IX: CYCLE TIME OBSERVATION

S.No	Process	SPM	No Of Pins / min	Cycle time in Sec
1	C A01 Machine	90	270	22
2	PC Machine	80		10
3	EC Machine	80		12
4	G- Machine	130	260	25
5	R-Machine	130	260	25
6	PS- Machine			18
7	R LM Machine			10
8	Packing			30
				152

TABLE X: WORK BALANCING

S No	Process	Cycle Time (sec)	Value Added Time (sec)	Non-Value Added Time (sec)
1	CA01 Machine	22	22	
2	PC Machine	10	10	
3	EC Machine	12	10	2
4	G- Machine	25	22	3
5	R-Machine (Twin Station)	25	22	2
6	PS- Machine	18	18	
7	R LM Machine	10	10	
8	Packing	30	30	
			144	

Work Time =144 sec

Takt Time = 31 sec

$$\# \text{ of Operators Required} = \frac{\text{Work Time}}{\text{Takt Time}}$$

= 5 Operators

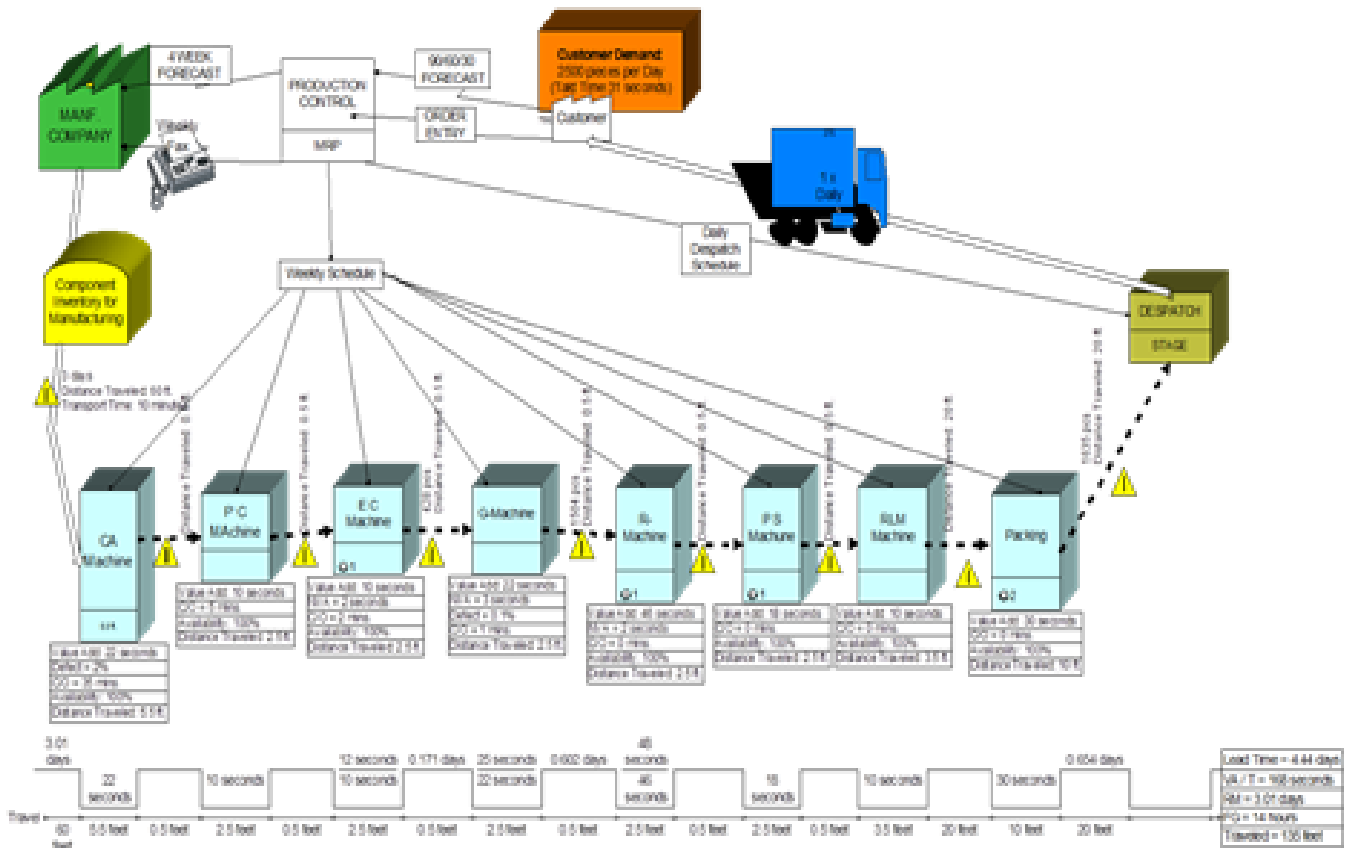


Fig. 10: Future State-1

WORK BALANCING

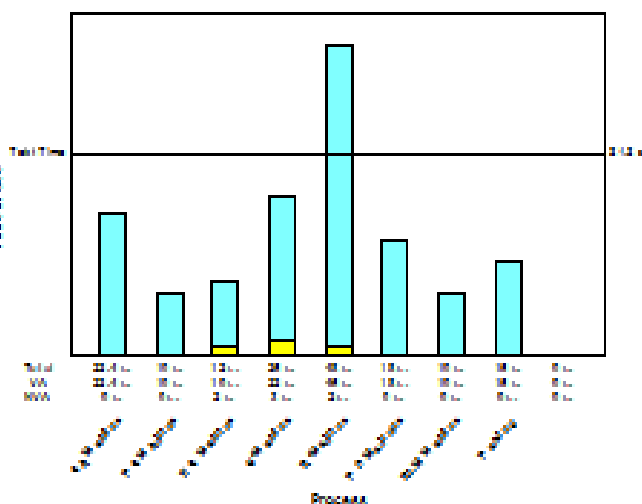


Fig 11: Work balancing in future state - 1

Work Balancing

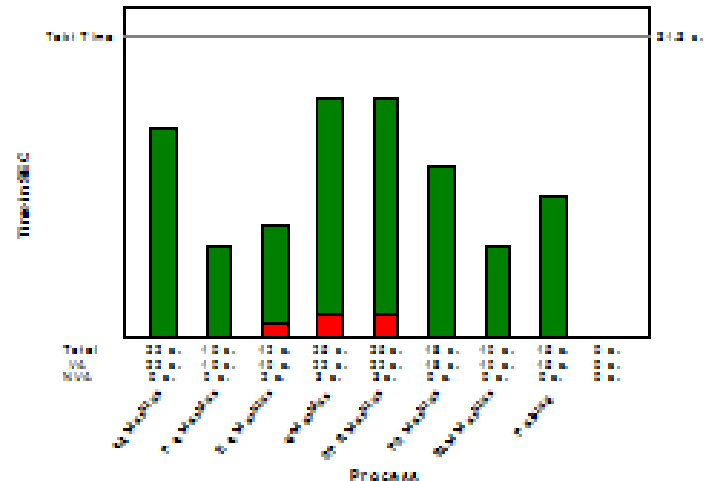


Fig 12: Work balancing in future state - 2

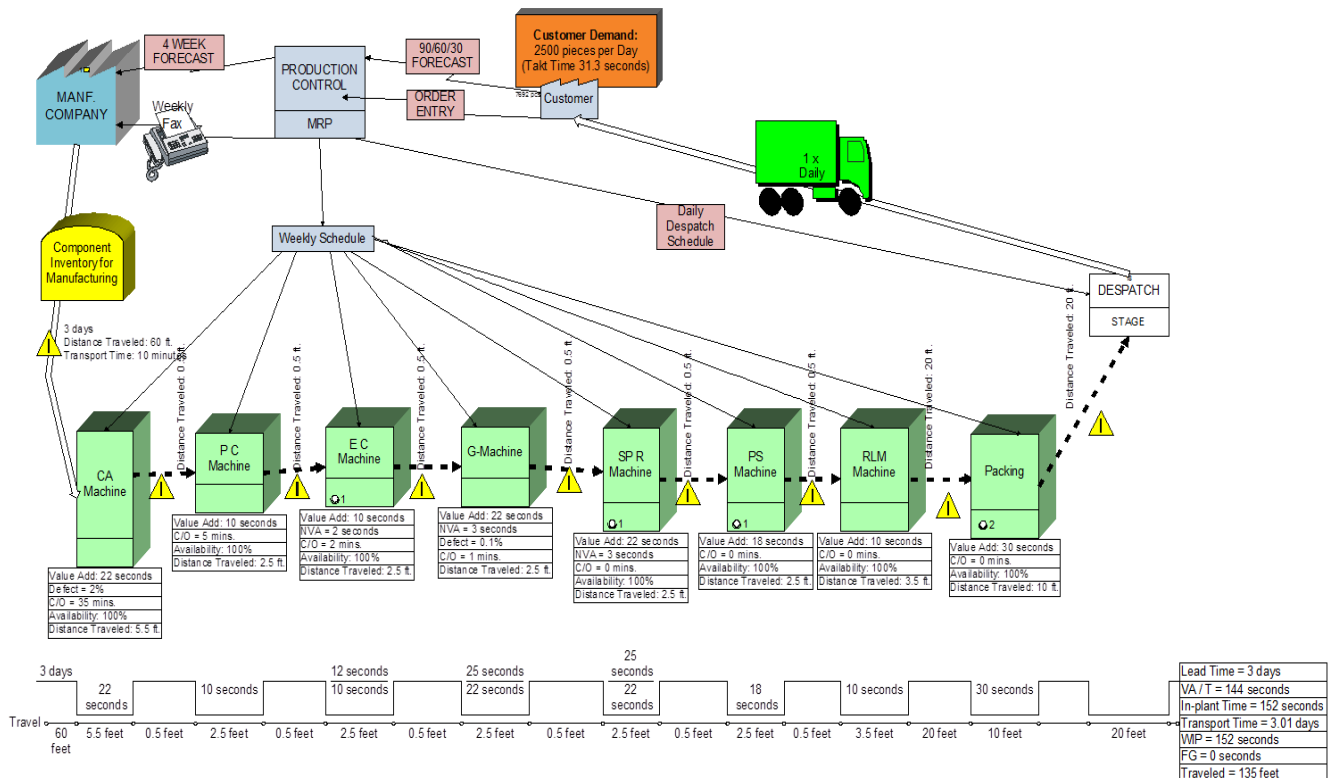


Fig 13: Future state – 2

5.4.3 New Optimal Layout: The optimized layout is show in Fig14. This layout modified using VIPPLANOPT software. The objective of modified layout is to minimize the transportation cost, inventory between the process and part waiting time.

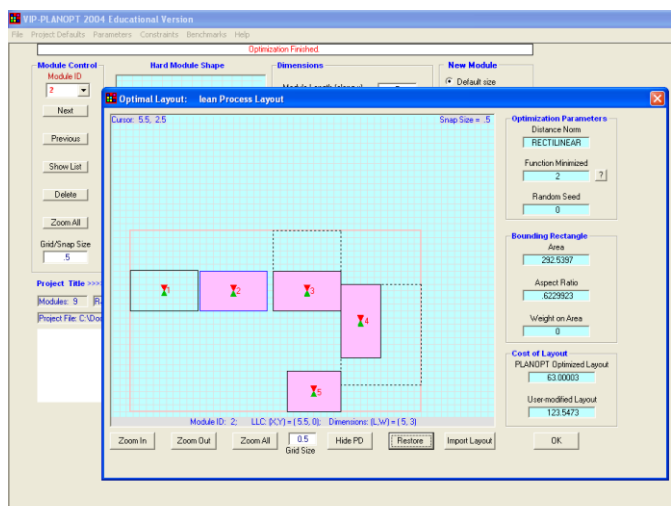


Fig. 14: Optimal Layout – VIP-PLANTOPT

6. CONCLUSION

From this paper, it was inferred that VSM is an ideal tool to expose the waste and to identify improvement areas. In this paper the effectiveness of lean principle is substantiated in a systematic manner with the help of simulation software in a systematic manner. Availability of information such as material flow, which facilitates and validates the decisions to implement lean manufacturing. This can also motivate the organization during the implementation to obtain the desired benefits. The results from these simulation software show that there can be much improvement to be made in the manufacturing of automotive components. It will help the companies to reach their ultimate goal of sustainability and profitable growth in the future.

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BIOGRAPHIES

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