International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

Assessment of Lean Manufacturing in a Manufacturing Industry

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Abstract: **Traditionally operated manufacturing industries are facing problems like low productivity, longer production lead time, high rework and rejection, poor line balancing, low flexibility of style changeover etc. These problems were addressed in this study by the implementation of lean tools like 5S, continuous flow, quick change over, total productive maintenance. After implementation of lean tools, results observed were used to assess the leanness of the plant floor. The key benefit of assessment is to identify the current state of production plant. And also to track the overall performance of the plant and it is evident that the leanness level can be improved by focusing on the key areas. This study is conducted in the steering knuckle manufacturing section in a manufacturing company. It includes time studies and current value stream mapping. Lean assessment was carried out using questionnaire which helped in diagnosing the lean status.**

Keywords: Lean Assessment, Time study, current value stream mapping.

I. INTRODUCTION

This project addresses the application of lean manufacturing concepts to the continuous production process sector with a focus on the manufacturing industry. After World War II, Japanese manufacturers, particularly in the automotive industry, were faced with the dilemma of shortages of material, financial, and human resources. Eiji Toyoda and Taiichi ohno at the Toyota motor company in Japan pioneered the concept of the Toyota production system, or what is known today as "lean manufacturing." The basic idea behind the system is eliminating waste. Waste is defined as anything that does not add value to the end product from the customer's perspective. The primary objective of lean manufacturing is to assist manufacturers who have a desire to improve their company's operations and become more competitive through the implementation of different lean manufacturing tools and techniques.

The term "lean" as Womack and Jones[1] define it denotes a system that utilizes less, in terms of all inputs, to create the same outputs as those created by a traditional mass production system, while contributing increased varieties for the end customer. Lean is to manufacture only what is needed by the customer, when it is needed and in the quantities ordered. The basic ideas behind the lean manufacturing system, which have been practiced for many years in Japan, are waste elimination, cost reduction, and employee empowerment. Hines and Rich [2] put forward seven kinds of value stream tools and tried to select tools from the perspective of reducing waste, which became the basis for value stream map decisions.

II. LITERATURE REVIEW

The term "lean" as Womack and his colleagues define it denotes a system that utilizes less, in term of all inputs, to create the same outputs as those created by a traditional mass production system, while contributing increased varieties for the end customer [3]"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 the customer's perspective, value is equivalent to anything that the customer is willing to pay for in a product or the service that follows. The seven types of wastes are as follows.

- Inventory
- Overproduction
- Over processing
- Defects
- Motion
- Transportation
- Waiting

'Leanness' refers to the degree of the taking up the lean philosophy in implementing in an organization. Several researchers investigated 'leanness' in the organization using some measures. Karlsson and Ahlstrom[4] utilized a set of measures and presented in a form of checklist to assess the extent of leanness.

In this paper, an assessment model was developed using questionnaire tool in a five point scale to rate the level of lean implementation in a machining line of a steering knuckle manufacturing industry. The objective is to systematically demonstrate, how lean manufacturing tools when used appropriately can help the process industry to improve their journey towards leanness. The organization of this paper comprises of Time study, Current Value stream mapping, selection of lean tools, assessing lean tools and Leanness score and its level.

III. OVERVIEW OF THE PROCESS

This process includes machining of steering knuckle right after casting process. There are ten stages of machining process which includes series of milling operations such as

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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- Boring
- Grooving
- Taper hole milling
- Face milling
- Drilling
- Tapping
- Reaming

IV. TAKT TIME

Takt time is the pace of production that aligns production with customer demands. Takt time is the ratio between planned production time and the customer demand.
Takt time is needed to calculate line balancing and adjust the process according to the production rate needed.
Planned production time = 480mins per shift
Number of shifts=3
Customer demand = 13000 set of pieces per month
Assuming the working days as 28 days by considering week offs.
Takt time = (28*480*3) / 13000 = 3:10 minutes=190 sec

V. TIME STUDY

Time study is defined as a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance. A time study was carried out for all operations of a steering knuckle manufacturing line by direct observation. The observed data was shown in Table 1.

Table 1.

M/C No.	Machining Time (Sec)	Handling Time (Sec)	Takt Time (sec)
1	130	50	190
2	130	50	190
3	125	50	190
4	130	50	190
5	144	60	190
6	300	75	190
7	103	60	190
8	130	60	190
9	113	60	190
10	0	300	190

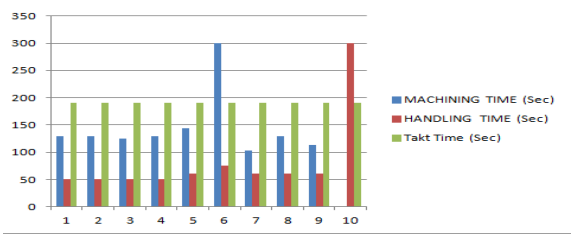

Fig.1.Graph showing the time distribution

The figure 1 portrayed that the number of operations which were less than the takt time.

From the plant floor, it was found that the Lead time was 23.55 days and Total cycle time was 2120 seconds. It opened a chance for improvement.

VI. A) VALUE STREAM MAPPING

Value stream mapping is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer. Khaswala et al [5] demonstrated the basic concepts of Value stream mapping and by implementing them in case of multiple flow value streams mapping that combine in case of a complex product. A tool used to visually map the flow of production shows the current and future state of processes in a way that highlights opportunities for improvement. It exposes waste in the current processes and production processes, mode of shipment of finished product to the customers.

VI. B) CURRENT VALUE STREAM MAPPING

The process begins by documenting the flow of material and information of the existing process, called the current state. The current state is typically drawn by hand, illustrating the received material, work-in-process, and finished goods inventory, cycle time, lead time, processes, flow of work-in-process between production processes, mode of shipment of finished product to the customers including transportation frequencies and time, and major customers or distribution system.

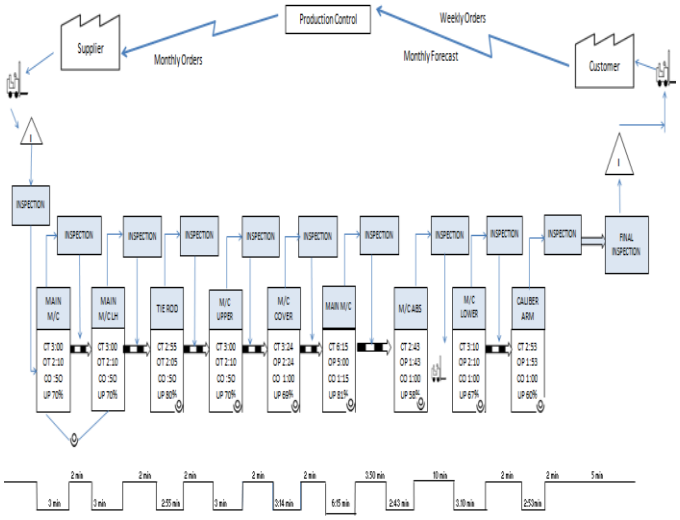

Fig2. Showing the current state mapping shows the total cycle time for each operation, change over time and uptime.

The current status of flow attracts the set of lean tools which will make progress in lean transformation. The selection of lean tools can be made using multi criteria decision making. Alireza Anvari et al. [6] proposed a modified VIKOR method to address the lean tool selection problems in manufacturing systems.

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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The set of lean tools necessary for lean transformation were listed in table 2.

VII LEAN ASSESSMENT:

Lean assessment is used to find out the leanness level of the firm, which is a method of consolidating results of various lean activities which were implemented in a firm.

Lean assessment helps to develop a gap analysis in order to find the places of improvement and map the overall success in lean transformation. To determine the relative score of each Lean activity, a questionnaire was prepared with the aid of the literatures [7, 8] taking into account the questions that must be asked to the selected members of the plant. The questionnaire is given the appendix. The efficacy of lean index is improved by quantifying the qualitative lean metrics. Leanness measurement is a multi-criteria decision making problem [9] and need the application of multiple lean metrics [10, 11]. It cannot be measured using one metric. Pakdil and Leonard [12] employed many quantitative lean metrics in their analysis of multiple aspects of Lean Manufacturing. However, their quantitative lean metrics that can be quantified are limited to aspects of LM performance.

Table 2. showing the Lean tools and Description

Lean Tools	Description
5-S	House Keeping tool.
Quality Process	Finding the good products from total products produced
Work Cells / PC's	Managing the work cell for easy accessibility
Visual Controls	Aid in operation controls visually.
Standard Work	Documentation of work in a standard way.
Quick Changeovers	Set up time reduction techniques.
TPM	Maintain the equipments effectively.
Continuous Flow	Create ideal condition for flow by reducing the work in process inventory.
Pull Systems	Let the down stream process to pull the product by using Kanban cards.
Levelling	Levelling the product volume and variety
Training	Employees have training on lean implementation.
Supplier / Customer Alliances	Supplier and customer support on lean practices.

Lean tools involved in lean implementation were assessed using the detailed questionnaire in a five point scale. The overall score of each lean tool represent the leanness level. The leanness level was assessed for 60 points carrying 5 points for each tool.

Table 3. Showing the assessment of lean tools

Sl.No.	Lean Tools	Lean Assessment out of 5 point scale
1.	5-S	3.5
2.	Quality Process	4
3.	Work Cells / PC's	3.5
4.	Visual Controls	5
5.	Standard Work	4
6.	Quick Changeovers	2
7.	TPM	2
8.	Continuous Flow	3
9.	Pull Systems	2
10.	Levelling	3
11.	Training	2
12.	Supplier / Customer Alliances	2

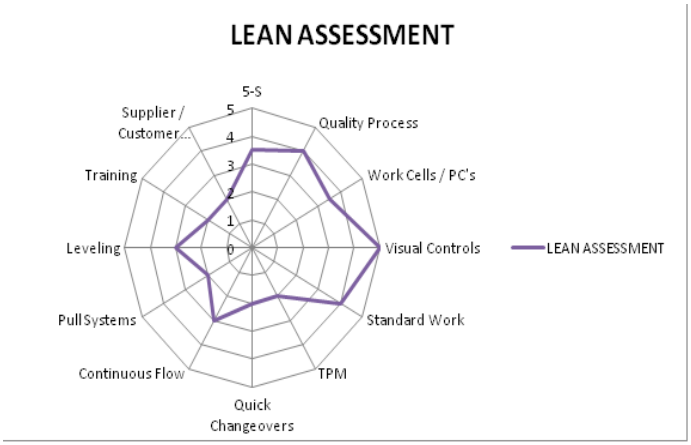

Fig.3 Radar chart showing the lean assessment of various lean tools in a five point scale.

Table 4. showing the remarks on the lean score.

Guide lines for assessment	Implied comments of the assessment.
<50 and<=60	Lean organization. Systematized focused on identifying and eliminating non value added activities.
<40 and <50	Exciting and popular movements within the organization.
<30 and <40	A good beginning in lean status ideas but is not systematized.
>30	No significant progress in race to become lean.

VIII RESULTS AND DISCUSSION

Time study is a tool used to monitor and document the time taken in each operation. It was shown in the graph of figure 1 that how operating time and handling time differed from Takt time. The current value stream mapping helps to map the flow of material and information. It was developed to show the number of operators involved, total cycle time and uptime. From the lean assessment scores, it was evident that the company has secured 36 points against the total of 60 points. The comments table showed the status of lean as in the beginning stage and required further systematized.

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ISSN: 2278-0181
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IX CONCLUSION

Lean implementation is a continuous improvement process. It involves proper implementation of lean tools and documenting the current status of leanness level. Time study and current VSM were carried out to map the current state of the shop floor. Lean tools employed in lean implementation were assessed using five point scale which showed the position of leanness level. Radar chart, a graphical tool was used to describe the present status of lean tools. So the key areas as projected using Radar Chart can be focused for further improvement.

APPENDIX

1. 5S	Scoring Range	Score
No formal workplace organization standard (5S) in place. No workplace order can be seen. Materials, parts, and tools not organized & have multiple locations.	0	3.5
Aware of the 5S principles but no training underway or completed. Non-routine cleaning takes place.	1 to 1.9	
Little training on 5S training has been done and some areas of the company have done red tagging and are showing signs of order. End of day cleaning by employees evident in these areas.	2 to 2.9	
Most areas have begun 5S. Materials, parts and tools assigned permanent positions. Employees participated in 5S.	3 to 3.9	
Periodical audit to asses 5S standards throughout the company. All areas working on the 4th "S" and are standardizing all of their processes. Don't depend on cleaning staff.	4 to 4.9	
5S sustainment is part and parcel of company's culture.	5	

2.Quality process	Scoring Range	Score
Rejections and Rework affect the production process	0	4.0
Jobs are inspected randomly to ensure the quality of the product in a lot only at the final inspection	1 to 1.9	
100% full inspection is carried out to meet the customer requirement	2 to 2.9	
Jobs are inspected with acceptable quality specifications in calibrated testing tools and the results well documented.	3 to 3.9	
Quality standards are followed and having at most importance to the customer satisfaction	4 to 4.9	

3. Plant / Facility Layout	Scoring Range	Score
Plant/facility has conventional layout with like processes & equipment making up departments, having the same kind of equipments in each work cell.	0	3.5
Some machinery/operations arranged by product/service families. Waiting, Large quantities work in process inventory exists.	1 to 1.9	
Some cellular arrangement of machines is evident. Different machines are arranged with in a cell to improve the flow.	2 to 2.9	
Cellular processing is clearly apparent in plant/facility. WIP in the cell is minimized and documented.	3 to 3.9	
Cross trained employees are there. Material Flow is carried out based on takt time to improve the flow.	4 to 4.9	
Output matched between cells. Pull systems exist. WIP & parts minimized. Emphasis on making facility quick in responding to customers. Layout impact the finishing of contracts.	5	
Fool Proof system is there that no bad products can be moved to the downstream process as the inspection is carried out in each process.	5	

4.Visual controls	Scoring Range	Score
When no visual data of process steps	0	5
Visual data on each of the process steps to make the operators understand their process and machine operations	1 to 1.9	
Visual data on process planning and time to complete charts	2 to 2.9	
Visual data on material flow and quality achieved in each of the process steps	3 to 3.9	
Visual data on condition of the equipment to do maintenance work, quality of the product and material flow	4 to 4.9	
Andon systems to provide Visual feedback system for the plant floor that indicates production status, alerts when assistance is needed, and empowers operators to stop the production process.	5	

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5. Standard Work	Scoring Range	Score
No standard work procedures exist. No understanding of the connection between continuous improvement and work standards.	0	4
Some standard work procedures are there to process steps, flow of materials.	1 to 1.9	
Standard work procedures on procedures of process steps, products flow and administrative processes function. Preventive maintenance, setup, quality, reporting, etc standards are not us	2 to 2.9	
Standard product work procedures are current and posted in the suitable areas for maximum availability.	3 to 3.9	
All standard work procedures can be seen in most areas and are readily available. Process owners know the what, when, where, why and how of their areas. Workers take ownership to use standards and keep them current.	4 to 4.9	
All standard work procedures are evident in every area. Employees have quick and free access.	5	

6. Total Productive Maintenance	Scoring Range	Score
Only Breaks down maintenance is performed. No formal preventive maintenance system in place	0	2
Preventive maintenance is done on an informally basis by the maintenance personnel or sub-contractors. No record on equipment history.	1 to 1.9	
A formal preventive maintenance system has been followed. Evidence of the system is visible and easy to understand. History is recorded.	2 to 2.9	
A daily/weekly preventive maintenance schedule is noticeable. The operators are concerned in the process of carrying out basic maintenance functions.	3 to 3.9	
Maintenance personnel & operators work together to finding the root causes and develop solutions.	4 to 4.9	
Operators take rights of the equipment maintenance and are trained to do the maintenance.	5	

7. Quick change over	Scoring Range	Score
Setup times not measured. No attempt to reduce setup on any piece of equipment or processes.	0	2
Setup times known and accounted for in scheduling the facility. Little evidence of knowledge of setup time reduction thinking.	1 to 1.9	
Some informal setup reduction has been attempted. Some training and some awareness on setup reduction exists.	2 to 2.9	
Formal setup reduction program in place. A team has been put together and attempts made to identify and separate internal and external activities. Awareness of the basic process exists.	3 to 3.9	
Formal setup reduction program has realized 50% reduction in some setup times. Some evidence of setup times being prioritized according to impact on the business.	4 to 4.9	
Setup times are less than 10 minutes on all critical pieces Approaches to reducing setup times well defined and widely understood.	5	

8. Continuous flow	Scoring Range	Score
No fixed flow for products, materials or information. Large batches and WIP exist.	0	3
Some evidence of product flow. Manufacturing sequences have been documented.	1 to 1.9	
Flow can be seen in some areas. Takt time is known to its fullest. Large batches and excessive WIP still exists	2 to 2.9	
Continuous flow can be evident in material and information flow. Takttime is used to reduce in lot sizes and queues.	3 to 3.9	
Most product families and information have been converted to flow. Batch sizes and WIP has been reduced and standard work is implemented	4 to 4.9	
All areas have been converted to flow. Value Stream is mapped on the entire production system. WIP is reduced.	5	

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9. Pull Systems	Scoring Range	Score
Production scheduling is based on forecasting. No pull systems exist within the supply chain.	0	2
Customer demand taken into consideration when scheduling production.	1 to 1.9	
Some form of kanban is used in some areas. The values of a visual signaling system are recognized.	2 to 2.9	
Kanban is used to schedule finished goods. Continuous improvement of the system is apparent. Customer demand drives the system.	3 to 3.9	
Kanban can be seen in all the areas. Precedence list of replenishment/pull system improvement projects exists.	4 to 4.9	
Customers, suppliers and production is aligned with kanban systems. Employees utilize kanban systems fully.	5	

10.Leveling	Scoring Range	Score
No mixed production exists for product families. Multiple lines used.	0	3
Mixed production consists of 2 or more units back-to-back in large quantities for each product family.	1 to 1.9	
Mixed production consists of 2 or more units back-to-back in small quantities for each product family on one line.	2 to 2.9	
Mixed production consists of only one unit back-to-back in large quantity for each product family on one line.	3 to 3.9	
Mixed production consists of only one unit back-to-back in small quantity for each product family on one line.	4 to 4.9	
Mixed production consists of small quantity, with consistent increments on one line.	5	

11.Training	Scoring Range	Score
Employees have no Training on Lean Thinking	0	2
Employees have little exposure or training on Lean Thinking	1 to 1.9	
Employees have enough training so that they can participate and contribute to Lean Thinking	2 to 2.9	
Employees have training so that they can be able to understand and explain applications of Lean Thinking	3 to 3.9	
Employees have enough skills through training so that they can practice or implement Lean Manufacturing	4 to 4.9	
Employees have enough training so that they can lead or innovate in lean thinking	5	

12.Customers/Supplier alliances	Scoring Range	Score
The customers or suppliers have no idea or participation in lean implementation	0	2
The customers or suppliers know lean concepts and lend their little support in lean transformation	1 to 1.9	
The customers/suppliers are willing to participate in lean implementation	2 to 2.9	
The customers/suppliers have made alliances in lean implementation throughout the supply chain	3 to 3.9	
The customer/supplier implement in their companies to improve the supply chain	4 to 4.9	
The customer/supplier shares the benefits of lean implementation	5	

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