Productivity Improvement by Applying Lean Tools for Manufacturing of Mechanical Seal

Aayush Shah, Sanket Sane, and Mehul Prajapati

Abstract Lean tools aid engineers and organization, to identify problems and various losses, waste and to reduce or eliminate them. Overall equipment effectiveness (OEE) is a successful lean tool to increase the productivity of the existing manufacturing process flow in a plant. The placement of various machine equipment, facilities for providing services, and staff amenities within a facility affects how effectively production is carried out. The paper gauges the OEE tool and plant layout to know the availability of the machines for manufacturing the seals, its efficiency, and overall quality of the product.

Keywords Lean tools · Productivity · Overall equipment effectiveness (OEE) · Plant layout

1 Introduction

Lean tools are grouped into three categories: just in time (JIT), waste elimination (WE), and flow management (FM). The lean tools can also be divided into improvement and exploration categories. Exploration tools are the lean tools used to systematically gather data and compile figures to determine the scope of improvement. Improvement tools for lean manufacturing include Andon, value stream mapping (VSM), overall equipment effectiveness (OEE), and Yamazani charts. The lean tools that are applied to change or improve upon the product or process fall under improvement tools such as 5S, heijunka, Jidoka, Kanban, Poka yoke, and single minute die

A. Shah
Purdue University, West Lafayette, Indiana 47907, US
e-mail: shah853@purdue.edu

S. Sane
Chem Seals Engineering Pvt. Ltd, Mumbai 400062, India

M. Prajapati (✉)
Production Engineering Department, Dwarkadas J. Sanghvi College of Engineering, Mumbai 400056, India
e-mail: mehul.prajapati@djsce.ac.in

H. Vasudevan et al. (eds.), *Proceedings of International Conference on Intelligent Manufacturing and Automation*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-19-7971-2_12

exchange. The improvement tools are used to change the situation after the exploration tools have been used to comprehend the current situation. The classification of the lean tool as an exploration and improvement tool further justifies the order in which lean tools are implemented in organizations. A study found that most of the industries, 90% tend to implement exploration and improvement tools to find out and eliminate unnecessary non-productive time and waste [2].

2 Overall Equipment Efficiency

Overall equipment effectiveness (OEE) is a way to monitor and improve the efficiency of manufacturing process. OEE has gained acceptance as a management tool for monitoring and assessing plant floor productivity. Three indicators used to measure OEE (availability, performance, and quality). These metrics assist in determining the plant's effectiveness and efficiency as well as in classifying significant productivity losses that occur during the manufacturing process. The setup and adjustment time that is lost due to downtime is minimized by the work study. Work study is the methodical evaluation of activity implementation strategies with the goal of enhancing resource utilization efficiency and establishing performance benchmarks for the activities being carried out. There are a number of work study techniques such as ergonomics, operations research, work study, and time and motion study to minimize setup and adjustment time to improve overall equipment effectiveness. It measures both efficiency (doing things right) and effectiveness (doing the right things) with the equipment's [3, 4].

OEE is a function of the three factors availability, performance, and quality. Availability is proportion of the time the machine is actually available out of the time it should be available. Performance efficiency is the portion of the OEE metric which represents the speed at which the machine runs as a percentage of its designed speed. Quality refers to quality rate, percentage of good parts out of total produced. The quality metric is a pure measurement of process yield that is designed to exclude the effects of availability and performance [3].

Based on the data collected, OEE is calculated by

$$\text{OEE }\% = \text{Availability x Performance} \times \text{Quality }\% \quad (1)$$

2.1 World Class OEE

A benchmark is used to compare the company's OEE to world class OEE. Table 1 below provides the world class OEE percentage.

OEE factor values are generally acknowledged, but they vary for various industries. For manufacturing, the value of world class OEE is 85% but for Paper Industry

Table 1 World class OEE [1, 4]

Factors in OEE (%)	OEE world class
Availability	90.0
Performance	95.0
Quality	99.0
OEE	85.0

and Cement Industry, the value is 95% and 80%, respectively [1, 4]. The sections that follow discuss OEE technique applied in a manufacturing firm and the proposed plant layout to increase the efficiency. The project was carried out on the shop floor of the Chemseals Engineering Pvt. Ltd.

2.2 Data Collection

On the shop floor, two CNC machines operate continuous. After observing the manufacturing process, various unnecessary downtime losses were observed. To study more about them, the previous three months data is listed for two machines given in Table 2.

As seen in the above data, the performance of the three months is good which means that machine is running at maximum speed. Quality is also good, but availability every month is low, and because of this, OEE is reduced. Availability is the percentage of time that machine is available for scheduled production compared with the amount of time they were actually producing. Figure 1 depicts the average down time loss due to factors like machine breakdown, no tooling available, power cut, inspection, rework, and CNC programme unavailable for three months which reduce availability.

Table 2 Data for CNC lathe machine and CNC milling machine

Elements of OEE	Data					
	CNC lathe machine			CNC milling machine		
	Oct 20 (%)	Nov 20 (%)	Dec 20 (%)	Oct 20 (%)	Nov 20 (%)	Dec 20 (%)
Availability	87.98	90.27	89.02	82.98	83.27	82.63
Performance	81.66	83.06	82.41	74.66	75.06	74.21
Quality	96.75	96.84	96.11	98.05	97.94	98.41
OEE	68.5	72.60	70.50	60.74	61.21	60.34

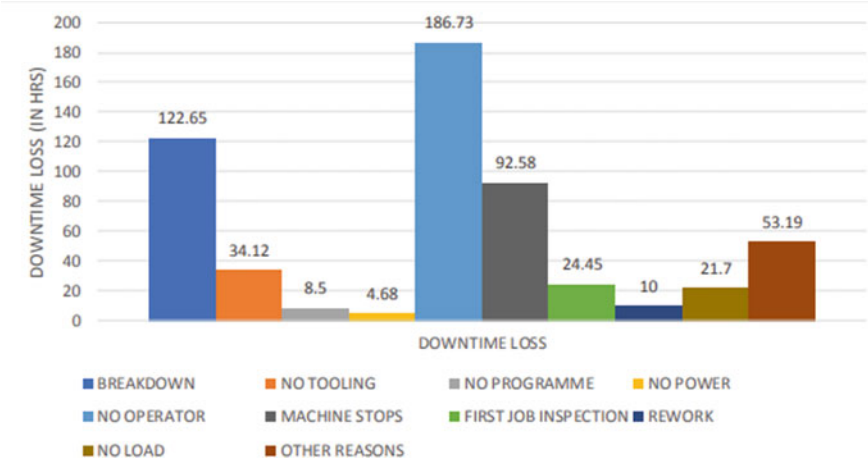

Fig. 1 Graph of average downtime loss of three months

2.3 OEE Metric Calculation

To find out more about the causes for low availability, OEE is calculated for the month of January 2021. After implementation of 5S, Table 3 records the shift data collected for month of January 2021 for two machines CNC lathe and CNC milling machine.

Gross available hours for production include 365 days per year, 24 h per day, and 7 days per week which is an ideal condition which excludes holidays and vacations. A shift's mandatory breaks (tea break, lunch break) are not included in the planned production time.

Table 3 Observed data of CNC lathe machine and CNC milling machine

Entities	Data for January 2021	
	CNC lathe machine	CNC milling machine
Shift length	10 h = 600 min	10 h = 600 min
Lunch break	30 min	30 min
Tea break	2 @ 10 min = 20 min	2 @ 10 min = 20 min
Total break	50 min	50 min
Downtime	60 min	86 min
Idle run rate	1 piece/4 min	1 piece/ 2 min
Total piece produced	98 pieces	176 pieces
Rejected pieces	4 piece	2 piece

Table 4 OEE for January 2021

Elements of OEE	Formula	Jan 21	
		CNC lathe machine	CNC milling machine
Availability	$\frac{\text{Operationtime}}{\text{Plannedproductiontime}}$	$\frac{490}{550} = 89.09\%$	$\frac{472}{550} = 84.36\%$
Performance	$\frac{\text{Partsproduced} \times \text{idlecycle}}{\text{Availabletime}}$	$\frac{94\text{x}4}{490} = 80.00\%$	$\frac{176\text{x}2}{464} = 80.00\%$
Quality	$\frac{\text{Goodpiece}}{\text{Totalpiece}}$	$\frac{94}{98} = 95.91\%$	$\frac{174}{176} = 95.91\%$
OEE	Availability x performance x quality	68.35%	63.26%

$$\text{Planned Production Time} = \text{Shift Length} - \text{Breaks} \tag{2}$$

The downtime and the speed losses are also ignored by the planned production time available. The down time includes equipment failures, machine changeover, tool damage, material shortage, and process warm up. The speed losses include product misfed, component jam, equipment aged, tooling wear, product flow stoppage, and level of maintenance of operator.

$$\text{Operating Time} = \text{Planned Production Time} - \text{Down Time} \tag{3}$$

The overall goal of OEE is to maximize the final machine run time which also includes the quality or the goodness of total parts produced. Quality losses refer to the situation when the line is producing, but there are quality losses due tolerance adjustment, warm up process, and part incorrect.

$$\text{Good Piece} = \text{Total Piece} - \text{Reject Piece} \tag{4}$$

To find OEE, use the data collected for the month of January 2021 from Table 3 with the above equations.

Table 4 gives OEE for the month of January of CNC lathe machine is 68.35%, and CNC milling machine is 63.26%. There is an enough scope for improvement in OEE.

2.4 Solution for Low OEE

To further increase the availability and OEE, below suggested points must be implemented.

(1) Machine breakdowns: Preventive maintenance programme must be implemented, and training should be given to operators, so that minor breakdowns can be avoided. Alternate tooling, enough manpower, sophisticated measuring

instruments and gauges, and work holding devices should be made available to reduce downtime.

(2) CNC machines should be integrated with the CAD software's to generate programme of any job immediately after loading job on machines. Instead of using SDN software for transferring programme from computer to machine use flash card wherever possible, so there will not be time loss due to programme transfer or computer hang.

(3) Time require for rework should not be considered as a part of OEE because these parts are made as per drawing before sending it for assembly.

(4) 5S Activity: 5S should be applied and practised in the industry. Necessary and unnecessary parts, tools, and equipments should be sorted and set in order. Tag should be attached, so that the operator will not spend more time in finding required parts. And the unnecessary downtime will be reduced.

3 Redesigning of Plant Layout to Increase the Efficiency

The simple flow of materials through a manufacturing facility can be significantly altered by small changes in the positioning of machines and equipments. The effectiveness of the entire manufacturing process is also impacted along with production costs. Designing a functional plant layout from the beginning is important because layouts are quite expensive. Using string diagrams and systematical layout planning, a plant layout can be redesigned to increase efficiency. String diagram provides basic details about the flow of material through the shop floor and the inter-relation of various activities [5].

3.1 Existing Layout

A measurement was taken of the space taken up by the machines, aisles, work-in-progress, storage area, raw material areas, and finished goods areas. In order to depict the overall picture of the manufacturing activities, flow process charts, outline process charts, and string diagrams were used. Figure 2 depicts the scaled drawings of the floor plans for the building [5].

The manufacturing process flow and the distance travelled in between the machine are mentioned in the below Table 5.

The job requires a total of 62 m of travel distance under the current plant layout. The prescribed travel length proposed by the company management is 35 m. Longest travel distance in the plant is the distance between the grinding machine and the quality control department, i.e. 13 m.

$$\text{Efficiency of current plant layout} = \frac{\text{Prescribed travel length}}{\text{Actual travel length}} = \frac{35}{62} = 56.45\%$$

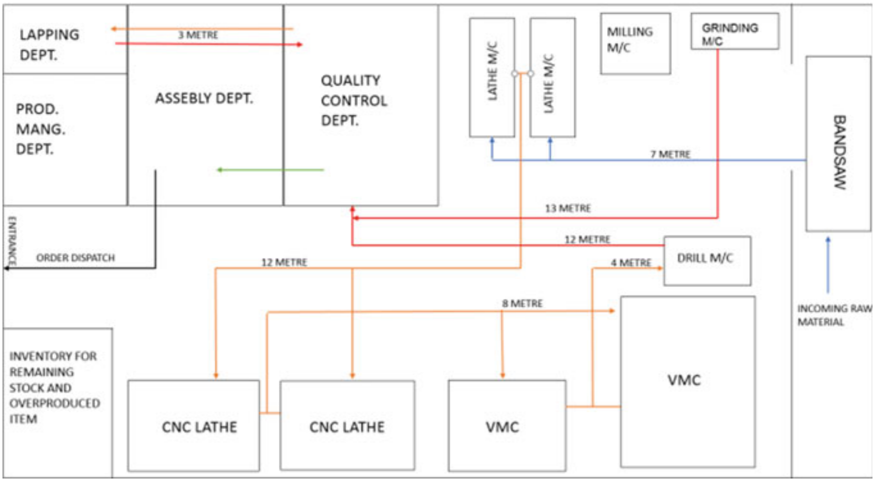

Fig. 2 Current plant layout

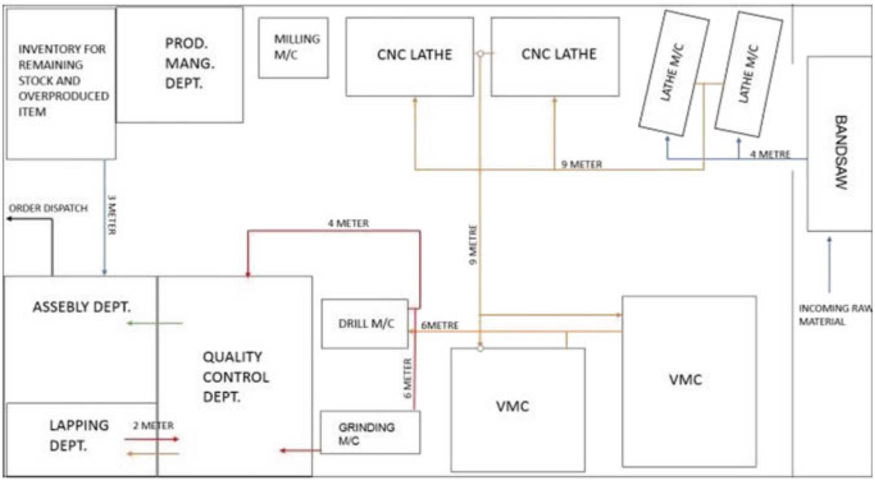

Fig. 3 Proposed plant layout

The main objective is to reduce the actual travel length of the material. By observing and studying the current material flow of the work piece right from the raw material to the finished product, a new plant layout is proposed.

Table 5 Distances travelled between machines

S. No.	From	To	Distance travelled (metre)	
			Current layout	Proposed layout
1	Material cut on the bandsaw	Conventional lathe machine	7	4
2	Conventional lathe machine	CNC lathe machine	12	9
3	CNC lathe machine	CNC milling machine	8	9
4	CNC milling machine	Drilling machine	4	6
5	After drilling on drilling machine	Quality control department	12	4
6	After final check in the quality dept	Assembly room	1	1
7	Grinding machine	Quality control department	13	6
8	Quality check department	Lapping department	3	1
9	Lapping department	Quality control department	3	1
Total distance travelled =			62	46

3.2 *Proposed Plant Layout*

String diagram indicates complex movements, back tracking, congestion, bottle necks, and over and underutilized paths on the current shop floor layout. By understanding the string diagram of the proposed plant layout, the material travelled distance between the machines and department is reduced as mentioned in Table 3. The location of quality control department, CNC lathe, and lathe machines was moved. Figure 3 depicts the proposed plant layout with the total travel length of the job as 46 m.

$$\text{Efficiency of current plant layout} = \frac{\text{Prescribed travel length}}{\text{Actual travel length}} = \frac{35}{46} = 76.00\%$$

A firm's long-term success can be adversely affected by the percentage increase (Eq. 5) and percentage decrease (Eq. 6) in transportation length when choosing which type of facility layout to use.

$$\%\ \text{improvement in plant layout} = \frac{\text{Proposed layout} - \text{Current layout}}{\text{Current layout}}$$

$$= \frac{76 - 56.45}{56.45} \times 100 = 34.63\% \quad (5)$$

$$\% \text{ reduction in transportation length} = \frac{\begin{array}{c}\text{Difference in proposed plant}\\ \text{layout material movement}\end{array}}{\text{Difference in current plant layout}} \times 100$$

$$\frac{(62 - 27)}{(46 - 35)} \times 100 = 40.74\% \quad (6)$$

The most effective manufacturing facility layout is chosen based on its adaptability to change in product demand and product mix in the future. Minimizing distance travelled is not always practical for all manufacturing industries. Whilst keeping the bare minimum of distance between machines and departments, it might be necessary to tolerate congestion in a particular area.

4 Conclusion

Productivity of the company is increased after applying lean tools and improving the design of the plant layout. After implementing 5S, downtime was reduced to 15–20%. After applying overall equipment effectiveness (OEE), various problems and unnecessary downtime losses were identified which are affecting the productivity. Redesigning of plant layout reduced the material travelling distance and minimizes unnecessary moment of material and workers on the shop floor.

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