

ANALYSIS OF PRODUCTION SYSTEM OF PHARMACEUTICAL COMPANY BY USING LEAN TECHNIQUE OF OVERALL EQUIPMENT EFFECTIVENESS (OEE)

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Abstract

The pharmaceutical companies generally lack maintenance equipment at working condition. However, increasing the availability of the maintenance system impacts the productivity and quality which ultimately satisfy the customers. Consequently, in order to overcome the challenges during the production system, it is necessary to implement the total quality management tool such as; total productive maintenance to enhance the productivity, quality and performance of the equipment which eventually increase the profitability of the company. So, data was collected from one of the reputed pharmaceutical company of Pakistan to evaluate the factors affecting the overall equipment effectiveness. Different analysis was carried out like fish bone diagram to find out the potential cause and Pareto chart was used to priorities the problem and also the descriptive analysis was conducted in which mean of availability, performance and quality were obtained 82.8% ,81.6% and 88.7% respectively. Total average OEE was 60%. After implementing of TPM and minimizing the six big losses. In order to minimize of losses like equipment failure, idling and minor stoppage and process defect. Our OEE was increased from 60% to 71%.

Keywords: Overall equipment Effectiveness (OEE), Total Productive Maintenance (TPM), six big losses.

Introduction

Industries plays vital role in the development of economy. The SMEs are becoming backbone to run the country. One of the important factors in industries to run for longer period of time is to have productivity, quality and effectiveness in production system. In those industries, pharmaceutical industry is more important compared to all because every country has demand of medicines 12 months in a year (Karam et al., 2018; (Aziz Ahmed, Shaikh and Memon, 2019)(Aziz Ahmed, Shaikh and Memon, 2019)Aziz Ahmed, Shaikh and Memon, 2019) . So, if we are unable to meet the standard in quality of medicines then it will be imported from other country and ultimately becomes costly (Susianti, 2020).

For pharmaceutical company, it is important to minimize the losses or defects to have quality product in minimal time. However, every industry faces issues during the production of product, but main objective is to minimize the issues and successfully enhance the productivity and quality of the system. If the production system doesn't run up to the set standard, then product cost will increase while compromising quality. So, it is utmost need of tool to enhance the availability, quality and performance of the system (Rajput and Jayaswal, 2012).

Overall Equipment Effectiveness can also be called as metric to measure the overall efficiency of the system in order to enhance the production system in more effective way. When organization uses their resources in optimum way it always reduces the end result cost. So, Overall Equipment Effectiveness is the handy tool to increase the rate of production, quality of the products and makes operations smooth during production. According to the literature, the world class overall equipment effectiveness is recorded about 85%, which is considered as one of the highest recorded OEE and can be set as a standard for other organizations (Sivakumar and Manivel, 2020). Currently, study suggests that the organizations making their efforts to achieve OEE as high as possible but couldn't reach up to the above-mentioned number because there are some limitations which affect OEE rating. Additionally, research suggests that the OEE can be enhance by reducing the six big losses which includes breakdown losses, Setup and Adjustment Losses, Idle and Minor Stoppage, Reduced Speed, Rework Losses and Yield /Scrape However, decreasing losses is the effective method to improve the quality and performance of production system and ultimately overall equipment effectiveness because it involves the multiplication of 3 terminologies i.e. Quality, Performance and Availability (Singh et al., 2020).

Literature Review

The lean manufacturing has shown the great potential in various manufacturing sectors throughout the world. There is great potential of lean manufacturing in the various manufacturing sectors of Pakistan as well. The maintenance operations in the manufacturing sectors of Pakistan can get the tremendous benefits by the implementation of lean techniques of Total Productive Maintenance (TPM) and Overall equipment Effectiveness (OEE) for the systematic maintenance of machines & equipments. The recent published case studies have shown the growing awareness and increasing scope of lean manufacturing in the major industrial sectors of Pakistan (Khan, 2018; Khan, Soomro, et al., 2020; Zaidi et al., 2021).

Large manufacturing sectors including the pharma, automobile and textile have initiated to adopt the various lean manufacturing practices. The case studies of the pharma, automobile and textile shown the proven substantial benefits of the applications of highlighted lean practices including Total Productive Maintenance (TPM), Overall equipment Effectiveness (OEE), 5S, Takt Time & Value stream mapping (VSM) (Khan, Marri and Khatri, 2020; Khan, Shaikh, et al., 2020; Rajput et al., 2020).

(Khan, Shaikh and Marri, 2020; Sahito et al., 2020) conducted the detailed systematic review of lean manufacturing practices in the context of pharmaceutical industries and presented the case studies of the pharmaceutical plants. The authors have investigated the lean manufacturing wastes at pharmaceutical plant by lean standards and then analysis is performed by using the statistical tools and techniques. The authors suggested the most suitable lean and Total Productive Maintenance (TPM) practices for eliminating/reducing the most significant wastes at the pharmaceutical plant and compared the pre and post study scenario. (Khan, Shaikh and Marri, 2020; Sahito et al., 2020) mentioned the substantial benefits of applying the lean practices of Total Productive Maintenance (TPM), Overall equipment Effectiveness (OEE), 5S and Value Stream Mapping (VSM) in the selected segments of the pharmaceutical industry.

(Kumar et al., 2020) conducted the case study for the Performance Evaluation of Motorcycle Assembly Line through the Lean Manufacturing Practices of Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE). The authors measured the performance of the assembly line through the lean tools and techniques and compared the OEE of the plant with the world class OEE. Authors identified the gap between the OEE of the plant and world class OEE and suggested the measures to reduce the gap.

(Lakho et al., 2020; Virk et al., 2020) discussed the implementation of Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE) in Maintenance Management. The authors have discussed few related case studies about the implementation of Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE) in the maintenance management activities of various manufacturing industries. The authors presented the detailed review of Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE) and discussed the implementations and benefits of Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE) in maintenance management activities of various industries.

According to the literature, the above mentioned factors are those on which overall equipment effectiveness mostly depended. Nevertheless, in pharmaceutical production of medicine system can't attain perfect 100% OEE because of six big losses which as mentioned above. If the production line of the organization manufactures products without any defects in them, then we can say that the optimum OEE is achieved (Dal, Tugwell and Greatbanks, 2000).

However, in order to make quality (maintain standards in every product) products within organizations, which have no manufacturing defects we must maintain high OEE which is nearer to the 100% (Saleem et al., 2017). At other hand, when a production runs at their maximum speed can be called as performance which is one of the important factors of OEE and when production line runs smoothly with no stoppage or breakdown while doing proper preventive and schedule maintenance can be called as availability.

1.1 Availability

Planned stop and unplanned stop is a major part of availability losses, in planned stops set up and adjustments like planned maintenance, cleaning and quality inspection, in unplanned stops in production due to equipment failure or breakdowns which have negative impact on OEE (Fekri Sari and Avakh Darestani, 2019). Short stops and short time of idle time are very important. These stops cause for different reasons included blocked sensor, miss feeds and jams.

$$\text{Availability} = \frac{\text{Available time} - \text{down time}}{\text{Available time}} \times 100 \quad (1)$$

1.2 Performance

Small stops and slow cycle are the big loss of the performance this is applies when the production does not run with full capacity. This could be because of equipment are poorly maintained, equipment is worn out, environmental factors, or operator issues. Such as operator errors, inexperience, availability etc.

$$\text{Performance} = \frac{\text{Running time} - \text{Performance loss}}{\text{Running or operating time}} \times 100 \quad (2)$$

1.3 Quality

It is considering quality losses, products are produced which does not meet with the quality standards, it means defective product as well as reduced yield is produced (Bengtsson, 2020). Examples are operator error, wrong settings and inefficient batch changeover process.

$$\text{Quality} = \frac{\text{Proceed amount} - \text{defect amount}}{\text{Proceed amount}} \times 100 \quad (3)$$

1.4 Six Big Losses

Every organization bear a different problem during the operation of machine, there are six big losses which are occur during the production, the important goal of OEE to reduce/ eliminate the six big losses, the six losses are Planned Stops, Unplanned Stops, Small Stops, Slow Cycles, Production Rejects and Startup Rejects (Nurwulan and Fikri, 2020).

1.5 Total Productive maintenance

(TPM) is used as a tool to rectify unplanned losses, failures, product defects and accidents. Total productive maintenance consists of 8 pillars which consist of following:

- Autonomous maintenance
- Process and machine improvement
- Preventive maintenance
- Early management of new equipment
- Process quality management
- Administrative work
- Education and training
- Safety and sustained success

Above all are the major pillars of total productive maintenance (Prasetyo and Veroya, 2020). However, in this research we used autonomous maintenance used as a tool to improve the productivity and effectiveness of the system. As autonomous maintenance can be defined as strategic tool for maintenance in which machines were continuously monitored by operators to make the adjustments and perform various tasks? Operator can be technician or executive employee (Corrales et al., 2020). So, autonomous maintenance deals to reduce the losses by doing preventive and schedule maintenance. This will impact overall equipment effectiveness and tend to increase up to world class OEE.

Secondly, in this research process and machine improvement tool which can be called as second pillar of total productive maintenance, used to enhance the overall equipment effectiveness (Corrales et al., 2020). Process and machine equipment can be called as focused improvement because it focused on process and machining improvement. It focuses on whole process and tends to improve the overall system which is the key objective of total productive maintenance. Meanwhile, it focuses on increasing the overall equipment effectiveness by reducing the impact of losses on process and machines (Li, Liu and Hao, 2021).

At last, the tool which is used in this article named as preventive maintenance. It can be called as planned maintenance to increase the efficiency, effectiveness and performance of the equipment's or machines. The tool can be used by means of collecting previous data based on maintenance (Dal, Tugwell and Greatbanks, 2000). However, there are number of machines in which maintenance is very compulsory without it can't run smoothly or effectively so, it is very important to conduct preventive maintenance at proper time to avoid big losses. Additionally, if maintenance hasn't done at specific time, then it will interrupt the production system. One of the major benefits of using preventive maintenance tool is that it will reduce the unplanned downtime (Singh et al., 2020). Additionally, it will help to greatly increase the efficiency and durability of the machines. At last, it will reduce in breakdown which tends to decrease the capital investment when machine is used at maximum potential.

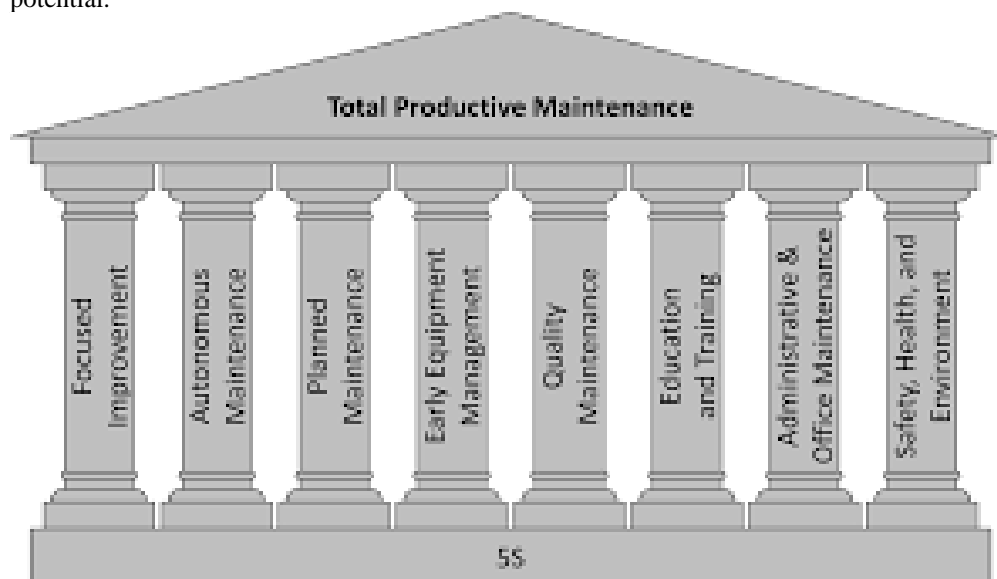


Figure.1, Eight pillars of TPM

Source: (Ahuja and Khamba, 2008)

Research Methodology

1.6 Data Collection

Overall Equipment Effectiveness which consists of three factors to enhance the productivity and effectiveness of the production system (Clarence and Mat Daud, 2020). However, in the research availability, performance and quality were considered. Additionally, data was collected of two months in which only one shift of workers consists of 10.5 hours producing about average of 634887 products before implementing overall equipment effectiveness technique. In the same way, availability consists of two major stops which include unplanned stops and planned stops. Planned stops mainly consist of schedule maintenance, planned maintenance or schedule stoppage in which workers were fully aware of operations and maintenance in plant. At other hand, unplanned stoppage in which partial breakdown or downtime occurs due to some random faults (Corrales et al., 2020). However, workers were unaware about the unplanned stoppage and likely to do the changeover adjustment, repairs etc. Our main focus was unplanned stops because these were the major threat to production system and tend to increase the chances of downtime. Now, performance also consists of small stops and slow cycles. Consequently, small stops consist of almost average of 38m per shift, short stoppages which were main objective. At last, quality consist of major element of production of the products because without the quality products named as defective. So, quality consists of production rejects and startup rejects (Sivakumar & Manivel, 2020). In which, production rejects consist of scrap that can be defined as the extra material which will be machined or removed during the production process.

1.7 Data Analysis

Quantitative approach is used to analyze the data in MS Excel software. The fishbone diagram and Pareto chart are used to elaborate the data and analyze to enhance the overall equipment effectiveness of the system (Nurwulan and Fikri, 2020).

Table1. Existing OEE data in company

	Min.	Max.	Mean	Standard Deviation
Availability (%)	79.8	88.2	83.4	2.4
Performance (%)	76.5	88.2	81.6	2.6
Quality (%)	88	90.2	88.6	0.7
OEE (%)	55	67	60	3

Source: Author Compilation

Pareto analysis is very common techniques which are used for prioritize the possible problem which high effect on the production (Bengtsson, 2020).

Table 2. Production losses

Production losses	Losses (hrs.)	Cumulative	Cumulative (%)
Printer problem	40.62	40.62	38
Aluminum foil change	29.04	69.66	65
Pressing device	16	85.66	80
Semi-finished	12	97.66	91
SOHNEL channel	7.34	105	98
The GARTEN	2.64	107.64	100
Total	107.64		

Source: Author Compilation

However, the problems are resolved by making the changes by utilizing this technique, by using this approach, we can find out the major problem and resolve them and our production of system will be increased, and which have high effect on the OEE rate. Pareto analysis is also known as 80/20 rule which is Pareto principle.

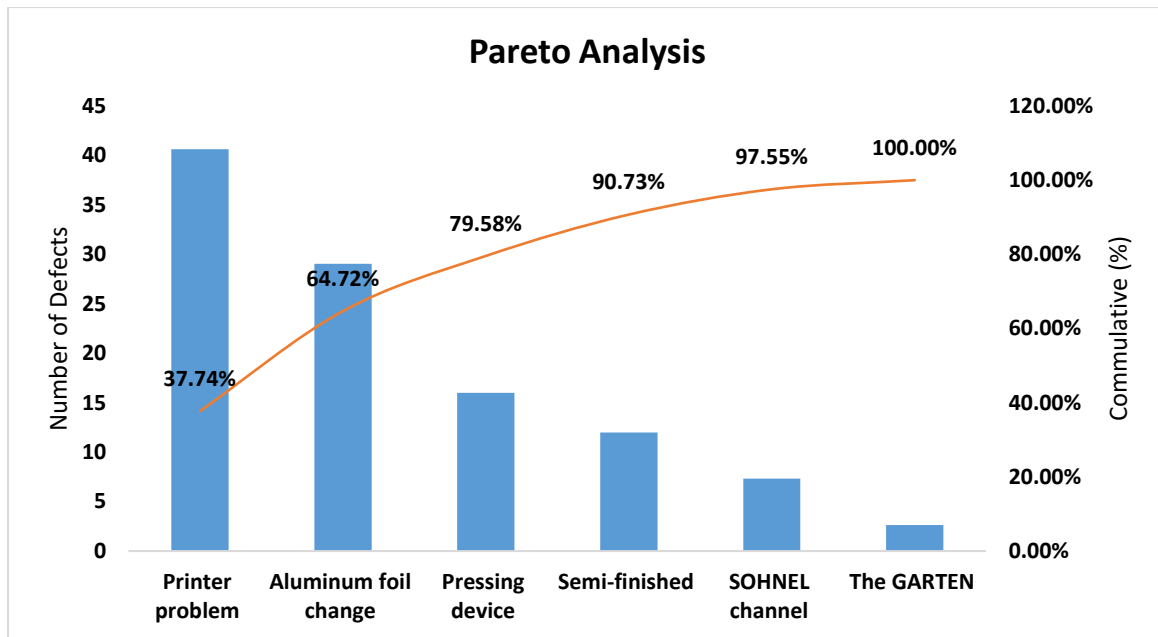


Figure 2. Pareto Analysis of Defects
 Source: Author Compilation

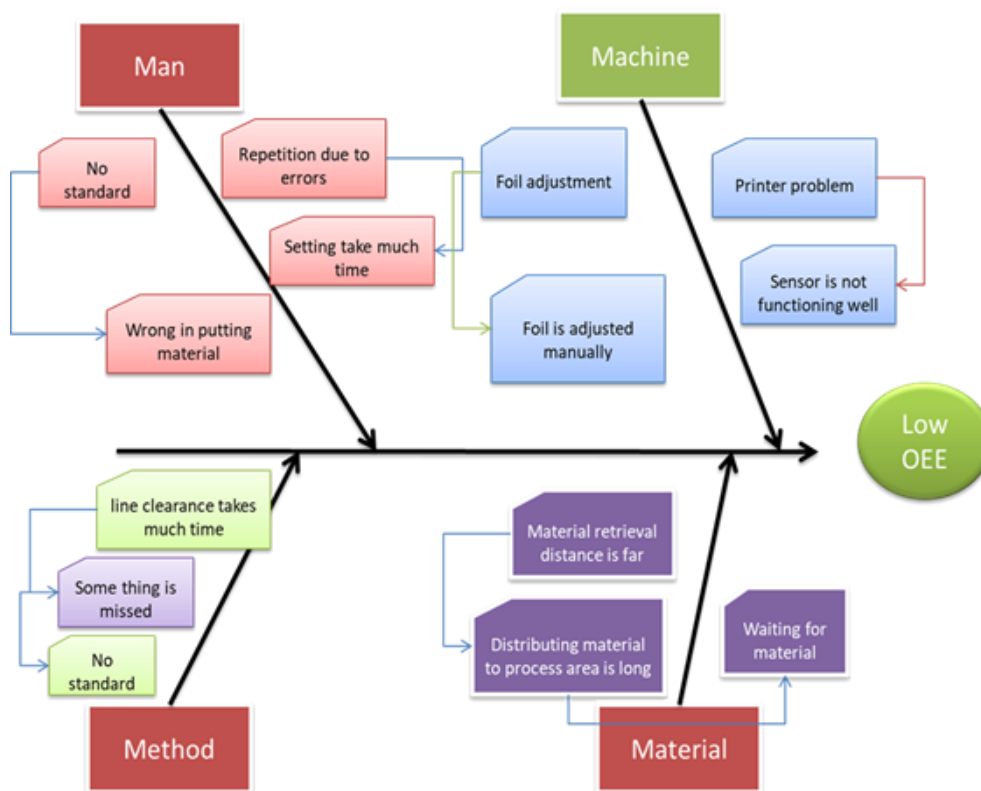


Figure 3. Fishbone/cause and effect diagram
 Source: Author Compilation

In the Pareto analysis there are different losses which are shown in the Pareto chart the most significant losses are the problem of printer i.e., 40.62 and problem of the aluminum foil change i.e., 29.04 and third major loss is the problem of pressing device i.e., 16 hrs.

These losses are considered as most priorities problem from the total loss i.e., 107.64 which are considered as vital few losses which hit on the OEE.

According to the literature (Bengtsson, 2020), cause and effect diagram is used for the identify the potential causes of the problems .fishbone diagram is developed by the DR Kaorru Ishikawa in 1943 which is popularly known as Ishikawa diagram/fishbone diagram/cause and effect diagram which includes line and symbol and

designed for the relationship of effect and cause. In fish bone diagram different causes like man, machine, method and material. In the causes of Man there is sub because no standard of work there is repetition in work and setting takes much time. In machine there is main cause like printer problem, foil adjustment, and pressing device. The third one cause is method in which line clearance problem, something is missed. The last one but not least potential cause is Material in which distance of material is far from the production and time is consumed for waiting of material. By minimizing these major potential losses our productivity of system is improved which directly impact the overall Equipment Effectiveness.

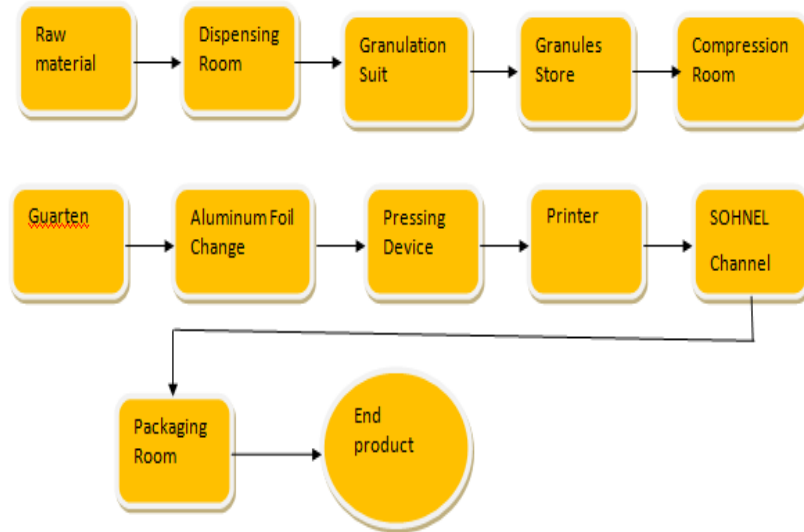


Figure 4. Process layout of the facility
Source: Author Compilation

In the availability factor, unplanned stoppage due to printer (see figure 5), foil or pressing device problems tend to increase the downtime which consists of 51 minutes average per shift result 82.8% availability (Fadhlurrahman et al., 2020). However, after implementing better planning, optimum usage of resources and planned maintenance which ensure fall off downtime up to 36 minutes to precede the availability about 85.7%. However, in the performance factor, short stoppage mainly happened in machine section, semi-finished, SOHNEL channel, Garten etc. Ramifications of these short stoppages were to use autonomous maintenance and focused maintenance which are pillars of total productive maintenance. So, it affects the performance and increases to 88.8%. At last, quality system rejects the scrap and produced about 634887 products with 72228 defective items which identifies the rate of quality about 88.6% only (Fekri Sari and Avakh Darestani, 2019). However, to lowering the defective number of products, 5s technique were used to control and enhance the quality of the system. In the result, 653400 products have been produced with only 4000 defective products in same input. Additionally, it increases the rate of quality of the system about 93.7% (Singh et al., 2020).

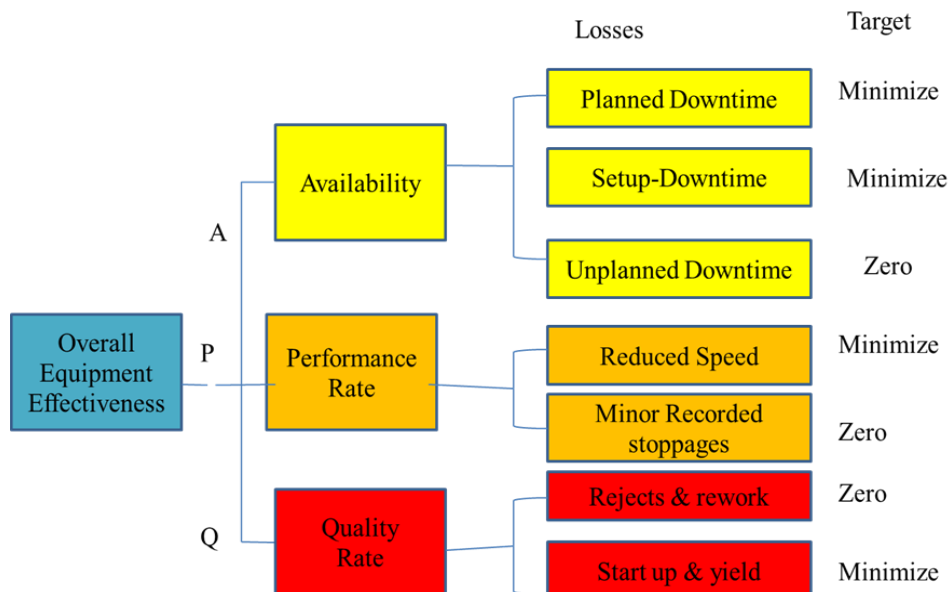


Figure 5. Categorization of losses

Source: Author Compilation

So, from above interpretation and results, it is concluded that by applying tools and techniques of total productive maintenance, overall equipment effectiveness can be increase because availability, performance and quality are the main factors of overall equipment effectiveness and factors are directly proportional to OEE. For example, following formula shows the relationship between OEE and Availability, Performance and Quality (Nurwulan and Fikri, 2020; Susianti, 2020).

In this regard, the data was collected from the case company which is presented below in the form of tables. The data regarding the production of specific article (ABC XXX) is presented in the table 3.

Table 3. Production Data of ABC XXX

OEE calculation ABC XXX	
Product name	Calcium Sandoz
Batch number	HJMAFW
Design labor	13
Actual labor	13
Labor efficiency	100%
Effervescent	RPM = 22, Punches = 22
Tablet / min	= RPM*Punches = 22*22 =484
Pack / min	= (tab/mint)/T20 = 484/20 ≥ 24.2
Pack /hr.	=24.2 *60 ≥ 1452
Total schedule time=1 Shift= 10.5 hours	10.5 hrs. = 10.5*60 = 630 min
Capable to produce in TST	= 10.5 *60*1452 ≥ 914760

Source: Author Compilation

Availability was calculated by using the data as collected from the case company presented in the table 4 given below.

$$\text{Availability} = \frac{525-90}{525} \times 100$$

$$\text{Availability} = 82.8\%$$

Table 4. Data collection for availability

Average Shift	Shift	Total Time (hrs) 10.5	Availability (%)								
			Available Time(525) (min)			Downtime (Time lost in)(90 min) Printer ,foil, pressing device					
			Planned Down time(105)			Breakdowns (min)	Repairs (min)	Change overs (min)	Adjustment (min)	Setups (min)	
	(6am-6:59am)	630 (min)									
	(7pm-7:59am)					5	2				
	(8am-8:59am)										
	(9pm-9:59am)					3	1				
	(10am-10:59am)					7	3				
	(11pm3333-11:59am)			Tea break	15				5	8	5
	(12pm-12:59pm)										
	(1pm-1:59pm)			Lunch break	30			2	1		
	(2pm-2:59pm)						3	2			
	(3pm-3:59am)						5	2	5	8	8
	(4am-4:30am)		Tea break	15			=25	=11	=15	=21	=18

Source: Author Compilation

Performance was calculated by using the data as collected from the case company presented in the table 5 given below.

$$\text{Performance} = \frac{435-80}{435} \times 100$$

$$P = 81.6\%$$

Table 5. Data collection for performance

	Shift	Performance Efficiency (%)										
		Long cycle time (min)	Reduced yield (min)	Idling /Minor stoppages (min)	Performance losses (min)	Running time						
						Total time min.	Planned Downtime min.	Downtime min.				
Average Shift	(6am-6:59am)		5	2	Semi finished SOHNEL channel The GARTEN (80)	630	105	90				
	(7pm-7:59am)	5		4								
	(8am-8:59am)			3								
	(9pm-9:59am)	7		5								
	(10am-10:59am)		4	4								
	(11pm-11:59am)	8		3								
	(12pm-12:59pm)			2								
	(1pm-1:59pm)		6	4								
	(2pm-2:59pm)	7		5								
	(3pm-3:59am)			4								
	(4am-4:30am)			2								
		=27	=15	=38								

Source: Author Compilation

Quality was calculated by using the data as collected from the case company presented in the table 6 given below.

$$\text{Rate of quality} = \frac{634887 - 72228}{634887} \times 100$$

$$Q = 88.7\%$$

Table 6. Data collection for quality

	Shift	Quality (%)		
		Total Quantity produced	Defective Quantity	Good unit produce
Average Shift	(6am-6:59am)	60154	6850	52854
	(7pm-7:59am)	60300	7100	53200
	(8am-8:59am)	60100	6900	53200
	(9pm-9:59am)	59100	6800	52300
	(10am-10:59am)	58500	7200	51300
	(11pm-11:59am)	65200	6300	50800
	(12pm-12:59pm)	58200	6522	51050
	(1pm-1:59pm)	63200	6620	48970
	(2pm-2:59pm)	56900	6980	49920
	(3pm-3:59am)	62500	7280	55220
	(4am-4:30am)	30733	3676	27057
		=634887	= 72228	=562660

Source: Author Compilation

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \tag{4}$$

So, after increasing above factors overall equipment effectiveness will increase as before using any technique OEE were 60% and after implementing tools and techniques of total productive maintenance results 71% which can be named as high OEE (Fekri Sari and Avakh Darestani, 2019). As above description in the form of Pareto chart given below.

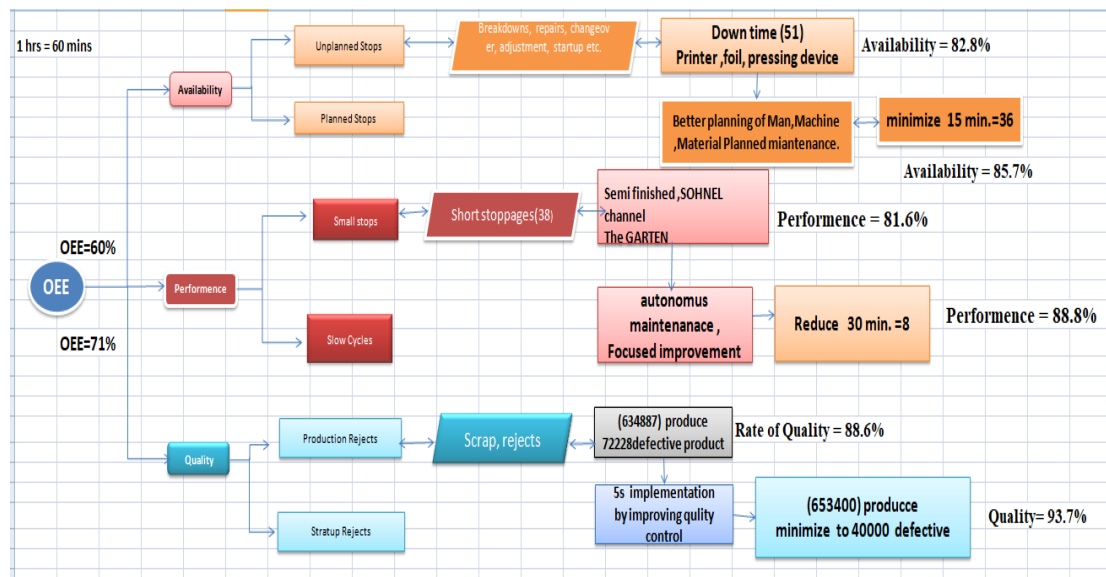


Figure 6. Reflection of improved OEE

Source: Author Compilation

Comparison of OEE before and after the improvement is presented in the table 7 given below.

Table 7. Comparison of current and improved OEE

	Existing OEE	OEE after TPM implementation
Availability(%)	82.8	85.7
Perfomece(%)	81.6	88.8
Quality(%)	88.2	93.7
OEE(%)	60	71

Source: Author Compilation

Conclusion

This study determined the overall equipment Effectiveness of (ABC XXX) the data of two month (per day 2 shifts). Each shift consists of 10.5hrs, Average OEE was found to be 60%, OEE is increased from 60% to 71% but OEE has greater impact of down time losses such as equipment failure, idling and minor stoppages , process defect and so on. More ever form above analysis conclusion was obtained that OEE is reduced hence by overcoming these losses our OEE rate is improved by the implementation of TPM and by maintaining the overall equipment at top working condition. In this way the overall equipment efficiency of system can be increased.

Future Implications

The company should do OEE on different machine which are producing the same type of product in pharmaceutical plant and the comparative analysis was carried outline this research plant was considered as single unit or single machine and producing the single product due to unavailability of unit wise reliable data. If there is flexibility to collect the data from different detailed unit wise section it can be easy to find out the root cause and conduct the corrective action which may obtain the more reliable OEE. With the passage of time the machine loses their efficiency after few years. If we measure the efficiency of machine it would be reduced because of wear and tear of machine part which may cause the failure and may hit the overall performance of the system. In future we can use the DMAIC approach, lean management system and the lean tools.

Even though the organization has made a lot of progress by the implementation of TPM by overcome the major losses such as over production, excess inventory, and defect in the production plant. Further studies were carried out the lean production system with TPM in order to produce the product to meet the customer requirement.

Conflict of Interest

There was no conflict of interest among the authors of the present research.

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