

Implementing Total Productive Maintenance in Yemeni Company for Industry and Commerce (YCIC): Case Study

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Abstract

Purpose: The purpose of this research is to design fundamental base for continuous improvement in maintenance that serves improving machine's reliability and raises the productivity, to fix strong products in the market with perfect quality and competitive price. Zero breakdowns, zero defects and zero accidents are the target to possibly improve productivity, save costs by reducing wastes and equipment longevity. Making the workplace is healthy organizational environment and better performance, increases the work team spirit by appropriate follow instruction of the implementation and mutual respect and understanding between managers and employees. **Design / Methodology / Approach:** The data were collected using questionnaire, company's documentation, interview and observations for 6 months at the lines of the company. The assessment is based on the overall equipment effectiveness (OEE), productivity and profitability approach. Cause-Effect diagram and Pareto chart techniques were used for identifying the problems in the production lines. The 8 pillars and others worksheets of TPM are used for 6 months period. Finally, OEE and its indexes were used as measuring of success the TPM implementation. **Findings -** The suggested scheme was effective in increasing the overall equipment effectiveness from 48 % to 85 % over a 6 months period. The parameters of OEE were a direct orientation of improvements in equipment availability, performance and product quality by highly recommendation on the pillars of TPM. This work may have exploits on the consistency of TPM nature to improve maintenance scheme for a generic system. The tools and worksheets presented can be helpful to managers and operators. **Originality / value:** Total productive maintenance (TPM) is one of the numerous diagnostic/prognostic maintenance strategies have been employed in this study. This research has implemented an integrated OEE and its parameters/managers and normal labors in order to clarify the cause / effect to make action for the critical/chronic lines to

remedy the low production. This is the first time that the TPM in this company has been placed and its impact is gained after that specific and short period.

Keywords: total preventive maintenance; availability; machine failure; overall equipment effectiveness

INTRODUCTION

Yemeni Company for Industry and Commerce (YCIC), was established in 1970, and is one of the largest companies in Yemen and Middle East for producing baked goods, confectionaries and sweets in Taiz city. Meantime, YCIC possess 2600 employees, 27 different production lines, and annual capacity of 120,000 MT. The lack of researches in Yemen regarding the industrial companies and their adequacy to the international standards in terms of productivity, made the image unclear. This research is to try to close the gap between the international criteria and the reality of actual production.

The total productive maintenance (TPM) is a maintenance methodology which consists of optimization of the industrial processes and maximizing the performance of the equipment to create high productivity (Kumar et al 2012, Kumar and Gahlot 2014). Empirical study was conducted about the high-end printing press machines /Packaging machines based on real time data and analysis was done to obtain achievable results. The questionnaires were distributed to assess information on successful implementation of TPM in the industry. Results obtained through the empirical study reveals the varying trends in the Overall Equipment Effectiveness (OEE) and Total Productivity of the machines taken up for the study.

It is possible to identify six sources of losses which decrease efficiency by interfering with production. These losses are equipment failure, machines breakdowns, startup- losses, defects/rework, idling loss, speed loss, set up and adjustment of machines. Thus, TPM can give several benefits to industrial units, such as an increased control over tools and equipment, a reduction of equipment failure by improving the response time, and reinforcing the coordination between production and maintenance.

Overall Equipment Effectiveness (OEE) of a machine plays a significant role in the present scenario, where right quality and right delivery at the right time are the major factors influencing a customer. Focusing to minimize the breakdowns, increase the performance and quality rate of machines so as to improve the effectiveness. The TPM techniques such as 5S, preventive maintenance and cleaning were effectively applied on the machine. The final result showed that the OEE improved by 5% in horizontal machining center and by 7% in vertical machining center (Nallusamy, S., 2016; Nalusamy & Majumdar, 2017). Manufacturing losses arising on account of such problems by prioritizing the root causes with the help of a pareto diagram and finally suggesting the solution to overcome these problems. A case study was carried out to improve the utilization of machine tool and manpower by initiating the practices through, TPM that would also form as a base for lean manufacturing.

TPM pillars are one of the administrative practices that began in Japan, and then it has been transferred globally to the whole world. The TPM is a philosophy claims that maintenance is not a duty of technicians only. It links between the protective maintenance, reactive

maintenance and total maintenance system that all employees and managers share responsibility toward the machines by raising the sense of ownership. TPM is a new way to look at maintenance where the operator of the machine does a lot of routine maintenance tasks. The challenging goal is to create a process of convergence between the operator and the machine and create a sense of ownership of the machine. The operator becomes a proud of repairing the machine and keeps it on good condition; not just reporting the faults to the maintenance department. Experience and research reports have proved that the implementation of the TPM leads to improve the performance measured by quality, productivity, cost, reduce losses and response to purchase orders, safety at work and high moral status of workers. Ahuja and Khamba considered everyone in an organization from top management to the smallest worker responsible for implementing TPM (Ahuja & Khamba, 2008).

Improving the availability of a critical production line through the total productive maintenance (TPM) methodology and supported by Lean Maintenance tools (Ribeiro, et al., 2019). An analysis is made of the initial condition of the line where the main problems are identified by employing several tools for this purpose, such as Mean Time between Failures (MTBF), Mean Time to Repair (MTTR), Overall Equipment Efficiency (OEE) and Availability (A). The implementing TPM supported by 5 S to improve the availability of an automotive production line, as the results showed increasing the MTBF and OEE and decreasing in MTTR.

Simultaneous implementation of TPM×TQM practices has a significant potential to improve manufacturing performance as compared to stand alone or separate implementation (Sahoo, S.; Yadav, S., 2020). Nowadays, many water treatment plants face the problems of equipment breakdown and water loss during water production process. A method to solve these problems is to implement eight pillars strategy (EPS), one of Total Productive Maintenance (TPM) strategy to reduce equipment breakdown, decrease water loss and enhance equipment effectiveness. Failure rate (FR), availability (A), performance efficiency (PE), quality rate (QR) was determined by evaluating equipment effectiveness through Overall Equipment Effectiveness (OEE) (Kigsirisin & Noohawm, 2016).

Nowadays, many diagnostic and prognostic maintenance planning have been employed in the field of maintenance; such as total productive maintenance (TPM), condition-based maintenance (CBM), computerized maintenance management system (CMMS), and reliability-centered maintenance (RCM) (Wakiru, Pintelon, Muchiri, & Chemweno, 2019; Sakiba & Wuest, 2018; Jain, Bhatti, & Singh, 2014; Prabhakar & Raj, 2014).

An integrated OEE/OBM diagnostic maintenance system to investigate the root causes of low productivity and machine failures in real production lines and suggested robust decisions on the maintenance duties (Amrani, et al., 2020).

A TPM strategy implementation in an automotive production line through loss reduction has been investigated and it was concluded that the line was possible to assess that the operating income of the line evolved positively from the moment the actions began to be implemented, therefore an 18 % increase was obtained in operating results compared to the initial period of the analysis (dos Reis, et al., 2019). Cybersecurity concerns for total productive maintenance in smart manufacturing systems were investigated. The research gaps and challenges are

identified to improve overall equipment effectiveness in presence of cybersecurity threats in critical manufacturing industries (Zarreh, et al., 2019). Design of a total productive maintenance model for effective implementation: case study of a chemical manufacturing company. Based on these results, knowledge and information sharing, operator involvement and training should be considered. The researchers then designed a TPM model which would result in effective implementation of TPM for higher competitiveness in the dynamic business environment (Mwanza & Mbohwa, 2015).

Overall equipment effectiveness (OEE) is an off-line metric tool and a TPM pillar that has been commonly implemented in industries to diagnose the failure of equipment and thus provide a support for the right decisions (Jain, Bhatti, & Singh, 2014; Nurprihatin, Angely, & Tannady, 2019; Cheah, Prakash, & Ong, 2020). Implementing Total Productive Maintenance in a Manufacturing Small or Medium-Sized Enterprise has been made by (Xiang & Feng, 2021). The framework structuralizes TPM deployment and binding different levels of organization into the program, from planning, implementation to sustaining the practices. The model recommends TPM implementation in three stages, namely plan, improve and sustain.

TPM is proven to play a significant role in improving maintenance and engineering performance in companies. It contributes strongly to an organization's plan of action by ensuring that equipment and facilities are well maintained, so as to provide improved quality of products and services (Elgharib, 2014; Aspinwal & Elgharib, 2013). TPM is a concept in which the purpose is to maximize the overall equipment efficiency, OEE, (Aminuddin, et al., 2016), thus creating a system free from interference. By concentrating on preventive techniques and involvement of operators, downtime can be minimized, and thus increasing the OEE. OEE-based developed maintenance approaches such as the TPM, lean manufacturing and six sigma require a precise and planned collecting data procedure, investing money to employ and engaging all levels of management and employees in the process (Cheah, Prakash, & Ong, 2020).

The preventive maintenance period and TPM period defined as decision variables are obtained simultaneously by maximizing the expected profit under TPM implementation. A numerical example is presented and a sensitivity study is developed to validate the proposed models (Chaabane, et al., 2021). The aim of this research is to quantify, through analytic development, the impact of TPM implementation in a company by calculating and comparing the profit made with and without TPM.

(Braglia, et al., 2019) exploits the complementary nature of TPM and RCM to design or improve maintenance plans for a generic system. The tools and worksheets presented can be helpful to practitioners and operators; while the integration of TPM and RCM is evidently a central issue in the maintenance management context, it has received limited attention in literature. The adoption of integrated TPM×TQM approach is beneficial for food and beverages and electrical and electronics sectors have been investigated by (Sahoo, 2019). Every operating sector embraces a diversity of manufacturing activities based upon their competing priorities.

A sequential TPM-based scheme for improving production effectiveness presented with a case study has been investigated to improve production effectiveness of equipment by facilitating

the implementation of the key principles of total productive maintenance (TPM) (Bataineh, et al., 2019).

The Total Quality Management (TQM) and Total Productive Maintenance (TPM) implementation initiatives as well as benefits attained through synergetic TQM-TPM implementation in the manufacturing organization to assess roadmap followed by Indian manufacturing entrepreneur toward affecting manufacturing performance enhancements (Singh & Ahuja, 2015). TQM-TPM initiatives can significantly contribute toward the better improvement of manufacturing performance in the organization, rather than TPM alone initiatives, also leading toward realization of core competencies for meeting global challenges.

The application of a hybrid simulation modelling framework as a decision-making tool for TPM improvement has been studied. Simulation results for the case study showed that intangible human factors such as worker motivation do not significantly affect TPM performance. What is most critical is ensuring full compliance to routine and scheduled maintenance tasks and coordinating the latter to align with rate of machine defect creation (Omogbai & Konstantinos, 2019). Impact of total productive maintenance (TPM) and total quality management (TQM) practices on operational performance and their inter-relationship was performed by (Modgil & Sharma, 2016).

Total productive maintenance and manufacturing performance improvement has been studied (Wan & Leong, 2017). The analytical results reveal that traditional maintenance initiatives and TPM implementation initiatives significantly affect manufacturing performance, but not top management leadership and maintenance organization. Top management roles and commitment are critical in the early stage to determine the master plan and initiate the implementation of the whole program. However, traditional maintenance and TPM implementation initiatives gradually enable engagement, proper planning, right execution and continuous improvement, ultimately improving the manufacturing performance indicators significantly.

Effectiveness of TPM implementation with and without integration with TQM in Indian manufacturing industries has been investigated to evaluate and extract various significant factors influencing the implementation of total quality management (TQM) and total productive maintenance (TPM) on business performance for the following approaches. TQM and TPM, are such popular initiatives employed by the manufacturing organizations as performance improvement techniques. These programs are employed world over for attaining customer satisfaction, reliability, productivity, market share, profitability and even survival (Singh & Ahuja, 2014).

The implementation of a maintenance management model based on total productive maintenance (TPM) in a production line of a metallurgical company, with high-precision equipment requiring effective maintenance to maintain the quality of the production process has been conducted by (Bartz, et al., 2014). After the implementation of TPM, and the results of these performance indicators were collected again after the application of the model. Thus, it is concluded that the TPM assists in improving industrial performance and competitiveness of the production line studied.

A total productive maintenance (TPM) implementation in a machine shop as a case study has been investigated. In their study, experience of implementing total productive maintenance is shared and investigated for a company manufacturing automotive component. Concept is implemented in the machine shop having CNC turning centers of different capacity (Singh, et al., 2013).

5 S techniques as a starting point to apply TPM in automobile industry. The study showed that the workplace must be cleaned and organized regularly to create suitable environment and perform the job in perfect way. Primary investigation showed that about 40 % of breakdown is due to improper maintenance. Therefore, they implemented TPM and found that the machine effectiveness is improved and the rate of achievement in the company is also enhanced by (Singh, et al., 2013). (Venkatesh, 2015) elaborated the importance of TPM and its necessity with making comparison between TPM and TQM, and also describes the maintenance stages in TPM implementation, and indicates the importance of educating the employees, arising from their vital role in TPM implementation.

A suggested a priority to training the staff of large airplanes companies. They classified TPM into business, equipment and people benefits based on customer suggestions for improvement and inspections. Their focus was directed toward material availability and quality and also calibration systems in performing works (Vayvay, et al., 2013). In a similar work, (Almeanazel, 2010) has described the objectives and benefits of the implementation of the TPM, the OEE, and the considering of six big losses in the industry. The analysis of the data before and after implementing TPM showed improving in the OEE from 55 % to 72 %, respectively. (Ananth & Vinayagam, 2012) studied the possibility of implements the TPM in tiny manufactory industry by supporting SWOT analysis. They conclude implementation of TPM in micro industry is difficult but SWOT analysis maybe accepted.

An evaluation and influence of implementing TPM in semi-automated manufacturing company of Bangladesh has been studies. Through measuring downtime and mean downtime, it was concluded the mean downtime remarkably decreased, leading the reduction of mean downtime up to 14.5 % (Rahman, et al., 2014). (Wakjira & Singh, 2012) analyzed the effect of applying the TPM in boiler plant, Ethiopian malt manufactory industry, starting with applying 5S techniques process that concentrate on work place environment to be suitable for work and focus on employer commitment to keep it clean and tidy all the time. The found the TPM implementation in malt manufactory industry showed the improving on OEE form 70 % to 80 %. (Singh, et al., 2013) indicated the tangible improvement in productivity and quality of product after implementing the TPM in automotive manufacturing company, with OEE improving from 63 % to 79 %.

The elements of TPM and its guidelines for OEE to improve plant performance had been investigated by (Kumar & Gahlot, 2014). They studied the impact of TPM on productivity, quality improvement, employee's development and organizational change. This leads to increase team spirit and group behavior of operators and staff. The significant improvement in productivity, quality and moral of employees, and a decrease in labor, maintenance and inventory costs are the prime benefits in which the company achieved them in the target period. (Nallusamy & Majumdar, 2017) studied the enhancement of OEE using TPM in a manufacturing

as well the study showed increasing of OEE by 15 % as a result of decreasing in breakdown losses, rework time, setup time and rework time. The impact of implementing Japanese 5S practices on TPM that aimed to determine the effectiveness of 5S practices in implementing of TPM in an organization performance. The result showed a huge effect of 5S principles in TPM implementation either directly or indirectly to achieve organization improvement and performance (Sharma & Singh, 2015).

The problem statement, according to the data collected, techniques and analysis, the substantial increase in technical downtimes in the industrial production line, especially in Cream Production Line (CPL), is a major challenge. Without an immediate action, technical downtimes could possibly continue increasing until it reaches alarming values of more than 20 % of total production time. Specifically, these downtimes did lead to raise the scrap rate, reduce the productivity, and increase losses in actual working time and machine parts. Periodic statistical data of YCIC production lines have shown alarming downtimes percentage in CPL. Furthermore, and technical reports recommended taking an immediate action.

This study is an attempt to bridge the gap by implementing the TPM concepts in CPL with a tension to reduce machine downtimes, bring scrap rate down, increase the productivity and minimize the costs.

METHODOLOGY AND PROCEDURES

Data Collection

The data were collected from the company at the important main lines allocated and suspected. The company has five separate production plants those are: Sweet Plant, Biscuit Plant I, Cake Plant, Biscuit Plant II and Wafer Plant. **Fig. 1** displays an illustrative scheme for the targeted lines and assets assigned and the methodologies applied in the present paper. Due to observation and questionnaires, and others techniques such as Pareto chart (**Fig.2**) and fishbone diagram (**Fig. 3**), the CPL was found as the chronic lines need improvements, where obviously packing area was having the most affected area in the CPL, which indicates the highest downtime value among the whole lines with downtime frequency of 103 hours as shown in **Fig. 2**. MTBF, MDT, availability (A), performance, quality products and overall equipment effectiveness (OEE) were determined. **Table 1** displays total scrap, planned and actual productions for the CPL in the year of 2018. **Table 3** indicates the mechanical, electrical, TDT and DT ratio for the CPL process area.

Table 1: Total scrap and Actual and Planned productions for Cream production before implementation, 2018

Month	Total scrap (ton)		Actual Production (ton)	Planned Production (ton)	Actual production Ratio (%)	Scrap ratio %
	waste	rework				
JAN	2.27	1.950	135.8	243.6	55.75	3.4
FEB	2.25	0.350	35.1	37.6	93.35	
MAR	15.02	2.783	383.3	458.1	83.67	
APR	11.33	2.350	416.5	647.3	64.34	
MAY	5.33	2.210	234.3	462.4	50.67	
JUN	6.66	2.648	344.8	388.5	88.75	
JUL	12.2	6.290	596.5	725.3	82.24	
AUG	5.7	4.040	384.3	414.8	92.65	
SEP	4.10	2.910	218.8	449.2	48.71	
OCT	8.85	3.621	423.2	688.6	61.46	
NOV	7.78	4.970	370.9	483.0	76.79	
DEC	10.4	2.820	245.2	521.0	47.06	
TOTAL	91.89	36.940	3788.7	5519.4	68.64	

Overall Equipment Effectiveness

Maximizing overall equipment effectiveness (OEE) is one of TPM goals, which take the machine effectiveness as its comprehensive view not in traditionally, view also it is focusing on machine loss. The OEE could be calculated as the following equation.

$$\text{OEE} = \text{Availability} \times \text{performance} \times \text{Quality} \quad (2.1)$$

The Availability Factors

The availability is the first index of the OEE, which is elaborates machines availability during the planned time. The availability concentrates on the operating time or the mean time between failures. Applying the following equations, availability can be obtained.

$$\text{Availability (\%)} = \frac{\text{Operating Time}}{\text{Planned Time}} \times 100 \quad \text{or} \quad \text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{DT}} \quad (2.2)$$

$$\text{Operating Time} = \text{Planned time} - \text{Downtime} \quad (2.3)$$

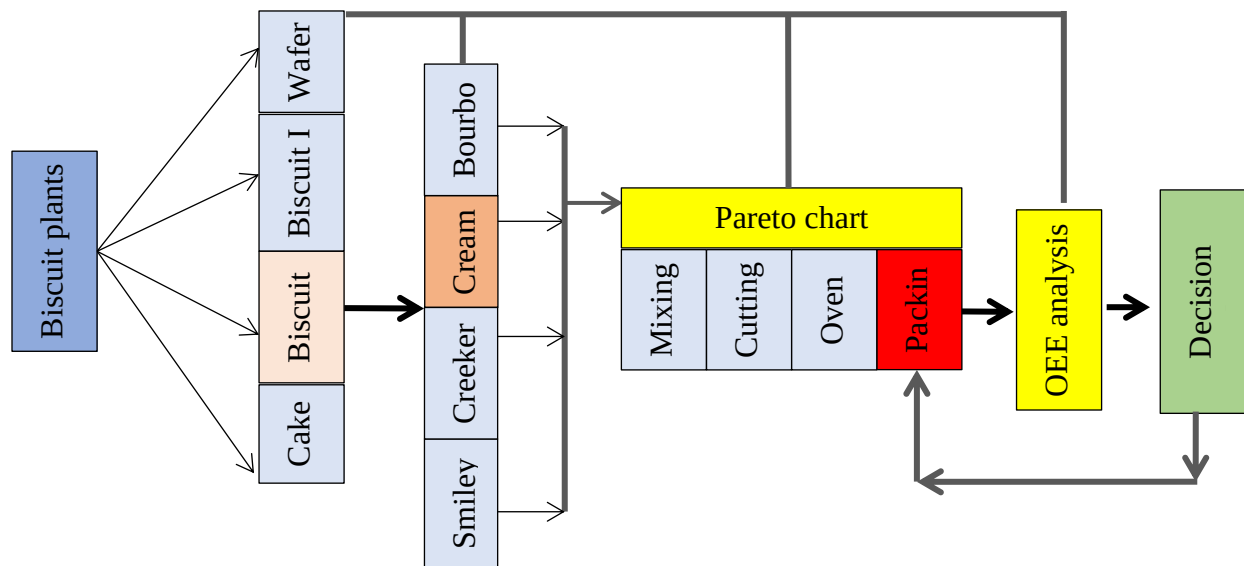


Fig. 1: An illustration diagram of the important production lines and the proposed methodologies.

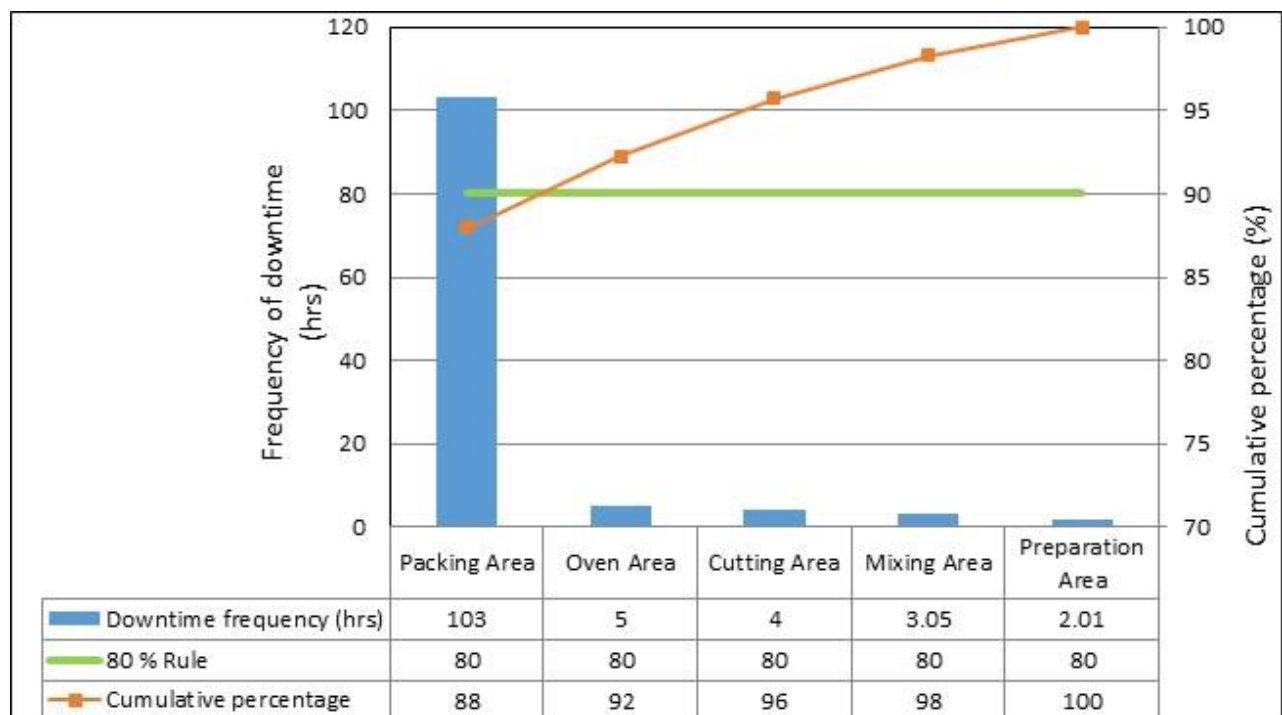


Fig. 2: Pareto chart for maintenance downtime analysis

The Performance Factor:

The performance factor is the second index of OEE, which focuses on three main factors of the ideal cycle time, standard time, and the actual product. The performance factor could be obtained using Eq. (2.4) and Eq. (2.5).

$$\text{Performance (\%)} = \frac{\text{actual product output} \times \text{standard time}}{\text{ideal cycle time}} \times 100 \quad (2.4)$$

$$\text{standard time (hrs/ton)} = \frac{\text{planed time}}{\text{planed production}} \quad (2.5)$$

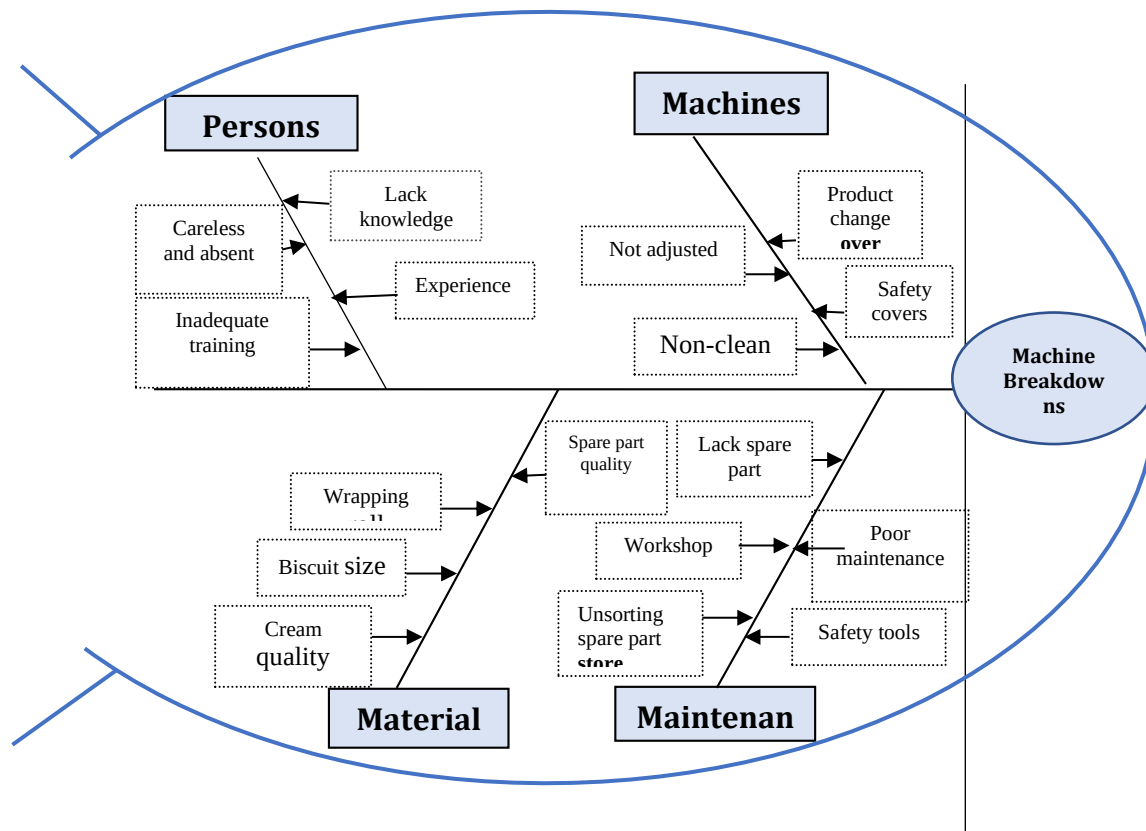


Fig. 3: Causes and Effect Analysis

The Quality Factors:

The quality rate is the third factor of OEE, could be computed using the total amounts of rework and scrap products for the operating year of 2018, as well the results obtained from eq. (2.6).

$$\text{Quality (\%)} = \frac{\text{Actual production} - \text{total scrap}}{\text{Actual production}} \times 100 \quad (2.6)$$

Table 2: TDT, MTBF and DT ratio for CPL before implementation TPM, 2018

Month	Execution Time (hr)	Mechanical downtime (hr)	Electrical downtime (hr)	Other Downtime (hr)	Total downtime (TDT) (hr)	MTBF (hrs)	Down Time ratio
JAN	192	5.10	6.00	2.00	13.10	178.90	30.53 %
FEB	40	0.40	0.70	0.30	1.40	38.60	
MAR	348	2.00	3.15	5.30	10.45	337.55	
APR	516	6.00	3.91	166.00	175.91	340.09	
MAY	416	0.10	0.40	212.41	212.91	203.09	
JUN	318	3.45	3.50	22.57	29.52	288.48	
JUL	592	7.20	8.13	76.50	91.83	500.17	
AUG	384	8.23	3.70	47.61	59.54	324.46	
SEP	340	6.27	3.20	189.00	198.47	141.53	
OCT	536	2.00	3.91	193.16	199.07	336.93	
NOV	468	270.00	5.10	124.32	156.42	68.58	
DEC	488	4.30	3.41	259.73	267.44	220.56	
TOTAL	4638	72.05	45.11	1298.90	1416.06	3,221.94	

Table 3: Maintenance downtime of CPL process area before implementation in 2018

Process area	Electrical downtime (hr)	Mechanical downtime (hr)	Total down (hr)	Downtime ratio %
Preparation Area	0.20	1.81	2.01	1.70
Mixing Area	0.85	2.20	3.05	2.60
Cutting Area	1.00	3.10	4.00	3.40
Oven Area	3.00	2.00	5.00	4.30
Packing Area	67.00	36.00	103.00	88.00
Total	72.05	45.11	117.16	100.00

Table 4: CPL OEE summarized as the data collected before implementation in 2018

Worksheet: OEE calculation – One year:		
Machine : CPL		
	Planned Production time (Loading time)	4,638.00
Availability	Time loss (breakdowns, waiting, changeover, line restraints, breaks), hr	1,416.06
	Operations time (Running time), hr	3,221.94
	Availability, %	69.47
Performance	Ideal cycle time (hrs) × standard time (ton/hr), ton	5519.22
	Actual output, ton	3,917.53
	Performance rate, %	70.98
Quality rate	Quality losses (Scrap and Rework), ton	128.83
	Good quantity, ton	3,788.65
	Quality rate, %	96.71

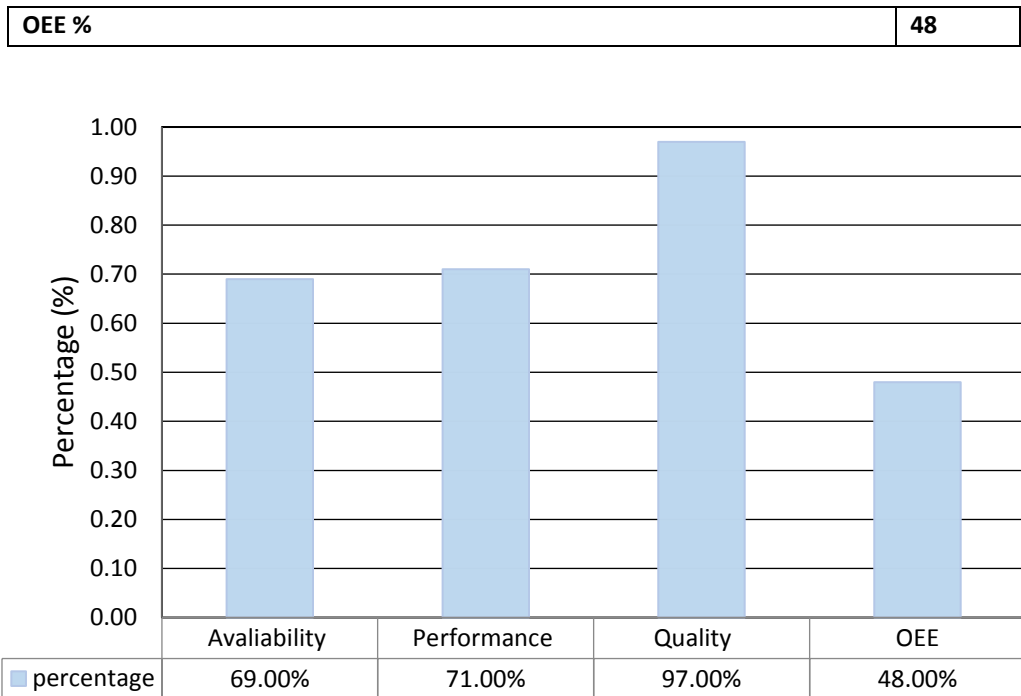


Fig. 4: OEE and its parameters of CPL before implementation

PLAN AND IMPLEMENTATION OF TPM

There are several steps for implementing TPM, as illustrated in the Fig. 5. TPM focuses on keeping all equipment in perfect working conditions to avoid breakdowns and delays in the manufacturing process. The implementation of TPM aims to eliminating the six big losses of breakdowns as shown in Table 5. To improve the machine's availability, efficiency and obtain high performance with good quality for products, it is highly recommended to be focused on the pillars of the TPM as shown in Fig. 6. TPM based on eight pillars as the following:

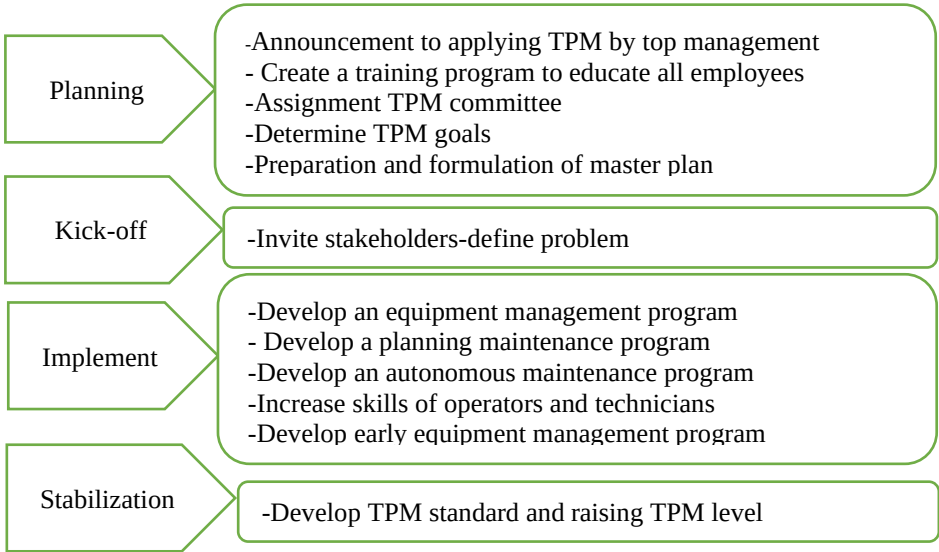
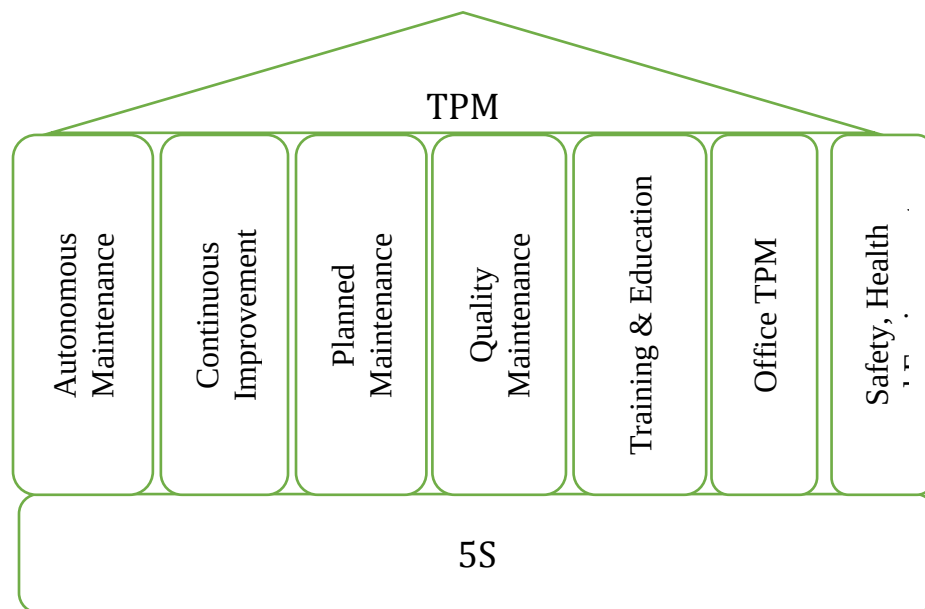


Fig. 5: Implementation steps of TPM

Table 5: Six big losses

OEE Factors	Loss category	Six big losses
Availability Rate	Down time loss	Breakdowns
		Setup and adjustment
Performance Rate	Speed loss	Speed loss
		Idling/minor stoppage
Quality Rate	Quality loss	Start-up Rejects
		Quality defects

**Fig. 6: TPM Pillars****5S**

5S is one of the TPM pillars which care about cleaning and organizing the workplace. When the workshop is not clean and sort, this leads to waste time in searching for the tools. Disorder workplaces do not encourage the operators and technicians to perform their tasks perfectly; also, it is difficult to apply safety principles in the cluster and unclean places. Clean machines facilitate maintenance work and make it easy to solve through fast uncovering for the problem. In addition, it reduces an accident, which is resulted from wastes and oil leaking.

To implement 5S in this study, technicians started cleaning, sorting, and organizing the workplace. Then, assigning one technician was assigned in each shift to control and monitor the workplace to keep it clean and organized, encouraging rewards policy to create a competitive atmosphere between technicians and operators to change this act to be a habit. **Fig.7** represents the implementation of 5S techniques of sorting spare parts, cleaning, and organizing the workplace.

Fully implemented 5S terms of sorting and organizing the items as critical, important, frequently used items, or items that are not needed as it's now. Unwanted items can be salvaged. Critical items should be kept for use nearby and items that are not been used in near future should be stored in some places which facilitate work tasks.

Autonomous Maintenance

Autonomous maintenance aims at developing operators to be able to take care of small maintenance tasks. The operators become responsible for keeping their equipment from deteriorating. The activities involved are very simple nature. This includes cleaning, lubricating, visual inspection, tightening of loosened bolts etc.



Fig. 7: Sorting, cleaning, and organizing workshop

Autonomous maintenance idea based on self-maintenance when the operator is directly responsible for repair takes care of the machine and asks help from specialists if needed. Most machine problems do not need that much experience to be handled. Autonomous maintenance gives us a lot of benefits like creating sense of responsibility and ownership in operators toward the machine, fast solving the problem before aggravating it. Sometimes losing bolts may make huge of deterioration in the machine if it fell down into a moveable part of the machine. The operators should know after any machine cleaning that it is necessary to perform the following steps to apply autonomous maintenance activity; **Fig. 8** represents the item number:

- I) To accurately lubricate all block chains, Chains with pushers of the sandwiching lanes (1), Chains of the overlapping device (2).

- II) Check the lubrication degree of the linear guides in the shutters movement devices (1), if it is not being sufficient lubricates them.
- III) There is sufficient oil inside primary and secondary rotors and inside each cream distributor, if this is not the case, tops it up. On the rotor, a cap (2) allows the check of oil level and the following topping up.
- IV) Inside the pump there should be enough oil for the lubrication, the oil level can be checked from the proper indicator (3) on the side of pump body, if necessary oil topping up. Do it through the cap (4) in the upper part of pump body.
- V) Grease the bearings for Propeller shaft of sandwiching chains (5), Propeller shaft of upper circuit chains (6), and Universal joints on sandwiching machine (7).

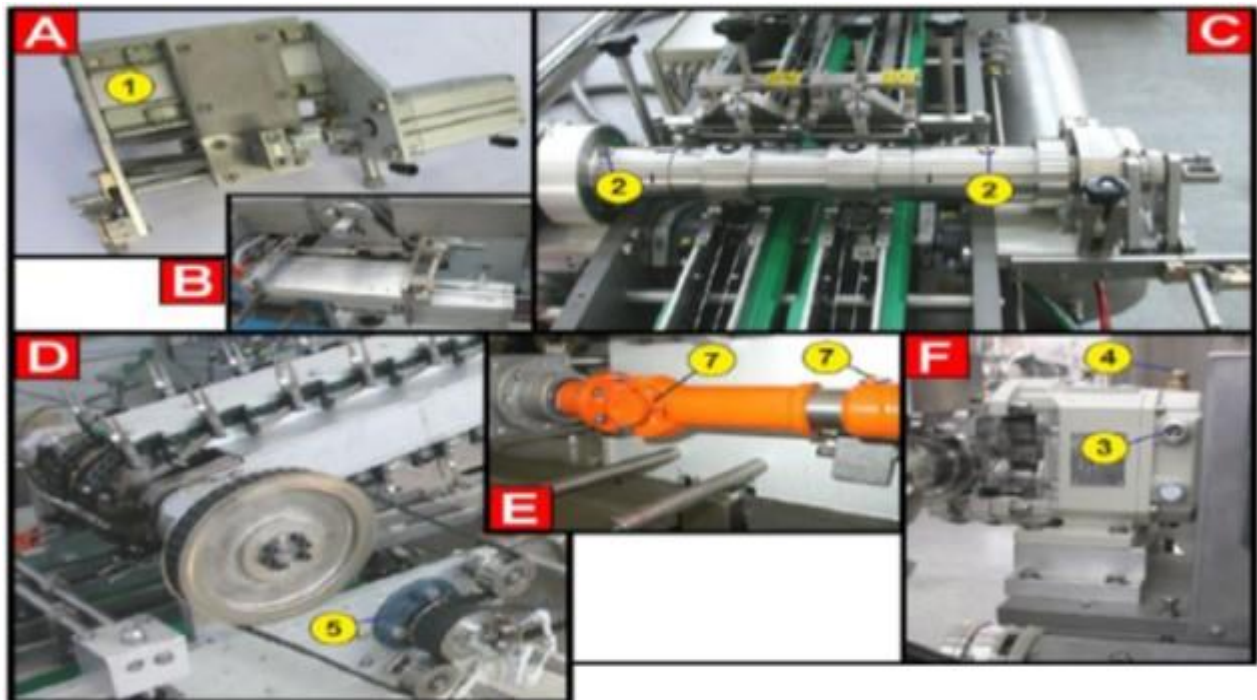


Fig. 8: Machine Item Positions

Continuous Improvement

TPM aims at sharing all the employees in continuous improvement of machines. Activate small group activities possibly plays an important role in implement TPM. Small group activities mean forming team from operators and technicians. Through small group activities, possibly they can solve a lot of production and technical problems, develop work environment, raise the moral of workers, increase the thinking and knowledge of the employees, create spirit of cooperation among the team and transfer a positive effect to other TPM pillars. For that, it needs to provide all tools required for the group, provide suitable training program, respect their ideas and activate the reward policy.

In this case study, to improving and solving the coils vibrator and controller's damage, after studied situations of vibrator it was found that vibrators legs base not fixed well as it shown in **Fig. 9 a**, In fact all vibrators touched with each other as it shown in **Fig 9 b**, that increase in the overload on the vibrator's coils that leads to damage a lot of controls and coils. For that, the

technicians made suitable gaps between the vibrators **Fig. 9 d** and reinstall the vibrator's bases also they add supporting fixers in the medial of legs as it shown in **Fig. 9 c**.

Large numbers of small improvements are more effective in an organizational environment than a few improvements of large value. This aims at reducing losses in the workplace and machine that affect line efficiencies. Fixed and supporting vibrators legs bases are tangible action that prevents coils and controllers of damage, which reduce downtime, and cost of replacing parts.



Fig. 9: Example of continuous improvement at packing machine in CPL

Planned Maintenance

Many industries have a perfect preventive maintenance program but it is not applied well. TPM is very concerned about implementing preventive maintenance program in accurate and good way, aiming to get zero downtime in the machines. Table 2.6 contains studied root and causes analysis problems in targeted machine and provide some important work activities that were implemented for it to reduce the downtime.

The evolved work efforts from a reactive to a proactive method and trained maintenance staff help to train the operators to better maintaining their equipment. That provides detailed data on the maintenance process. The team identifies the optimum approach to maintaining the equipment, starting with a Periodic Maintenance (Time-Based Maintenance) system before introducing Predictive Maintenance (Condition-Based Maintenance) systems.

Education and Training

Education and training make multi-skilled revitalized employees whose morale is high and who are eager to come to work and perform all the required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient to know only Know-How but they should also learn Know-why. By experience, they gain Know-How to overcome a problem and what to be done.

Training maintenance and operators staff plays an important role in raising maintenance performance to reduce repairing and maintenance time. TPM takes a great attention in increasing qualification of operators and technicians staff to provide them with special skills in discovering the problem and give the best suggestion for improvement. This point focuses on:

Operators Training:

Caring about training the operators in fixing and tidying the bolts, lubricate and greasing the gears, how to detect the problem, how to check machines parts, how to analysis the causes of the problem by using modern techniques, such as, fish-bone and how to keep the machine clean every time.

Technicians Training:

Providing advanced courses in lubricating and greasing the machine, PLCs7-200, PLCs7-300/400, pneumatic controls, PLC screen programming, TPM methods; prepare maintenance program, problem analysis methods, electronic circuit1+2, and English courses.

Managers Training:

Training production and engineering seniors, concerning their jobs. Providing courses like professional training, administrator management, work supervising, work design and raising staff skills and enthusiasm.

Quality Maintenance

Quality Maintenance aims to assure zero defect conditions. It does this by understanding and controlling the process interactions between manpower, material, machines and methods that could enable defects to occur. Perhaps it can understand of what parts of the equipment affect product quality and begin to eliminate current quality concerns, and then move to potentially quality concerns. Modifying the production machines to prevent the non-conform product of exiting.

Quality maintenance aims to achieving zero customers complains through providing good quality product by eliminating the defect causes. **Tables 6** elaborates some customer complaints and its treatment according to the historical data exists in the company.

Office TPM

Office TPM must be followed up to improve productivity, efficiency in the administrative functions, identify, and eliminate losses. Through office TPM, the inventory levels in all parts of the supply chain reduced, reduced repetitive work, better utilized work area, reduced loss and clean work environment.

To create TPM office to administrate, implement and evaluate TPM program, which required full support from top management. Office TPM is responsible for the implementation of each TPM pillars gradually and making coordination between them, providing awareness about office TPM, identifying losses in each function in relation to plant performance, identifying the scope for improvement in each term and helping them to solve problems in their circles.

Table 6: Customer complain treatment

Problem	Causes	Solution	Period
Unfolding packet	Weak heating	Check sealing temperature	Weekly
	Disc heating pressure	Check piston function	Weekly
	Film quality	Check film quality	Monthly
	Sensor damage	Replace new sensor	Yearly
	Heaters damage	Change heaters	Yearly
	Lowling temp. setting	Set suitable temperature	Daily
	solenoid valve not working	Repair valve or replace it	Yearly
	Solenoid coil burn	Replace coil	Yearly
	PLC signal	Check PLC temperature	Weekly
No date on packet	Domino printer fault	Check printer ,clean the head printer, add ink	Daily
		Check signal	Daily
		Check program setting	Daily
		Reset machine	If-Needed
		Check relay signal function	If- Needed
Not full pieces in packet	Machine sensor fault	Check sensor response	Weekly
Burn pieces	High temperature	Set temperature degree	3 Hour
Low packet weight	Low pieces weight	Check pieces weight and row material	2-Hour
Wrong date	Fault in write	Check before printing	Weekly
Biscuits sandwich without cream	Cream printer	Check solenoid valve	Weekly
	Pieces sensor	Check pieces sensor	Weekly
	response timing	Check response timing	Weekly
	Stencil	Check stencil position	Weekly
	Stencil valve	Repair valve	Daily
	Cutting wire lose	fix wire	Once-Occur
Informal pieces shape	Row material	Check production recipe	1-Hour
	Change temperature degree	Check burners state	Once-Occur
	Burner fault	Repair fault occur	Once-Occur
		Plan for maintenance	Weekly
Rotten biscuits	Weak heating	check heating system	Weekly
	Humidity	Check temperature setting	Daily
		Check burner temperature	Daily
		Check storing conditions	Weekly

Safety, Health, and Environment

Implementation of safety, health, and environment aims for zero accidents, zero health damage and zero fires. Actually, this starts at designing stage only. Operators should be given safety training. In fact, without appropriate safety training, they are not allowed to operate the machines. Workers are required to use appropriate safety measures such as helmets, shoes, gloves, glasses and covers. In health aspect any effects on health are considered as well appropriate measures taking for smoking, extraction, and ventilation.

Also, prepares the workplace with adequate lighting and ventilation, monitoring cleanness of the workshop to remove wastes, oil leaking from the working floor to be safer, forming a committee to enlighten the employees on the importance of safety and health environment, holding seminars, and lectures, regarding safe and clean work environment.

As a result, to decrease the machine's covers damage, the engineers changed the plastic covers to stainless steel grids to improve machine safety as shown in **Fig.10**. Also adding protection frames for the jaw cutting area to prevent occurrence of any accident (**Fig.11**).

To ensure the continuous applying of TPM standards and for keeping the work in the best manner and results monthly checklist was put for monitoring the implementation of TPM. TPM planned maintenance actions for packing machine are displayed in **Table 11**.



Fig. 10: Adding Safety Frames



11: Modifications of safety doors

Fig.

RESULTS AND DISCUSSION

Overall Equipment Effectiveness

After implementing the TPM in the CPL, data was collected for four months and evaluated and all the requirements calculations were performed to enable us clearly evidence the new suggestions. **Table 7** presents an actual, planned production and capacity production ratio after implementation. Comparing between **Table 1**, **Table 7** and **Table 8**, obviously the actual capacity is shown that it increased from 68.64 % to 99 % as well conclusively it is seen the total scrap rate reached to 1.99 % instead of 3.4 % before implementing. The productivity was 68.64 % of the planned production capacity, which is undervalue of the world standard, explaining that the company is working run –to – failure without any scheduling maintenance implementing. **Table 10** and **Fig. 12** reflect that the OEE was incredibly jumping from 48 % to 85 % due to the improving in the scheduled maintenance, intensives, and follow up the recommended TPM implementation as a result of this work.

The Availability Factors

The productivity in Biscuit II was very low due to low availability and performance and the products quality of the production lines was classified as disfigured products as shown in **Table 1**. The low productivity seems comes from the low availability and performance. Dramatically availability after implementation jumped from 69.64 % to 89 %. This improvement is attributed to huge action implemented in the lines where they had lack to the required maintenance as well as the recommended comprehensive and scheduled preventive maintenance. 5 S are taken into account and the incentives to the labors were noticed to increases the beneficial of the investment in this field and frequently become much better. Remarkably MTBF increased and the MDT decreased, which are the indicator of availability. It is noteworthy to see that the total downtime declined to 11% contrary before implementing it was 30.53 % as presented in **Table 2** and **Table 9**.

The aforementioned diagnosis inferred that CPL was at abnormal situation and is must take into account immediately action to implement effective maintenance and invest sufficient budget for maintenance or to purchase new systems with controlling tools. As results of this work, highly recommendation is suggested to spend money for efficient maintenance as TPM.

Table 2 and **Table 4** display downtime, MTBF, availability, defect products, performance and OEE of the five assets of CPL. Obviously, the values revealed that among the five equipment of CPL, the packaging machineries are the most fault machines as well besides, a Pareto chart of cumulative downtime of CPL explained the same diagnosed results as shown in **Fig. 2**.

Fig. 7, 8, 9, and 10 explain the improvement of productivity where the availability and MDT were remarkably improved when the company credits the new scheme of TPM to the managers and employees.

The Performance Factor

Before and after implementing TPM, the data and calculated values of the performance, one parameter of OEE, are depicted in **Table 4**, **Fig. 4**, **Table 10** and **Fig. 12**, respectively. It is noteworthy that the performance of the machines of CPL particularly and labors generally increased to 98 % on contrary when was 71 % before implementing the TPM in the targeted

line. The remediation of CPL with the techniques and proper actions of TPM was taken place using little bit change in the tools and credited the sufficient budget for TPM. The ideal cycle time, standard time, and the actual product are the three main factors that are responsible for the performance. The higher administrative and employees' commitments in the implementing of TPM actions on the targeted are the core of the improvement. The crucial regulations and disciplinary between all administrative sections also are the forefront as well as the incentives to improve the performance which is the one member of the triangle of OEE.

The Quality Factors

The quality of the product away of defects is the main factor of OEE. By fishbone diagram (**Fig.3**), the maintenance and labors at the CPL were found the most factors are impacting on the productivity. Lack knowledge, careless, absence and inadequate training; and unsorting parts, poor maintenance are the diagnosis resulted in this research. The presence of faults in the products plays significant rule to decline the customer's demand or refrainment of the products. The little gap between the quality before and after implementing (**Fig. 4 and Fig. 10**) in the present work is bit in the values but it is tremendous considerations in the added value and reliability index for the products and consequently in the company.

Table 7: Actual, planned and capacity productions after implementation in 2019

Month	Actual production (Ton)	Planned production (ton)	Actual capacity Ratio (%)
MAY	400.017	370.734	108
JUN	384.725	409.561	94
JUL	384.317	414.806	93
AUG	550.916	546.372	101
TOTAL	1719.975	1741.473	99

Table 8: Wasted and rework scrap after implementation in 2019

Month	Rework (Ton)	Wasted (Ton)	Total Scrap (ton)	Rework Ratio (%)	Wasted Ratio (%)	Total Scrap Ratio (%)
MAY	2.80	7.1	9.9	2.0	0.70	2.70
JUN	2.90	11	13.9	3.0	0.80	3.80
JUL	4.00	5.7	9.7	1.5	1.00	2.50
AUG	0.20	0.62	0.82	0.11	0.04	0.15
TOTAL	9.90	24.42	34.32	1.4	0.60	1.99

Table 9: Downtime Details after implementation in 2019

Month	Execution Time (hr)	Mechanical downtime (hr)	Electrical downtime (hr)	Other downtime (hr)	Downtime (DT)	Availability A %	Downtime ratio %
MAY	394	4.24	2.18	44.93	51.35	86.77	13%
JUN	339	4.9	5.02	27.57	37.49	88.94	11%
JUL	384	5.3	3.63	50.61	59.54	84.49	16%
AUG	488	3.26	5.00	27.02	35.28	92.77	7%
TOTAL	1,605.00	17.7	15.83	150.13	183.66	88.56	11%

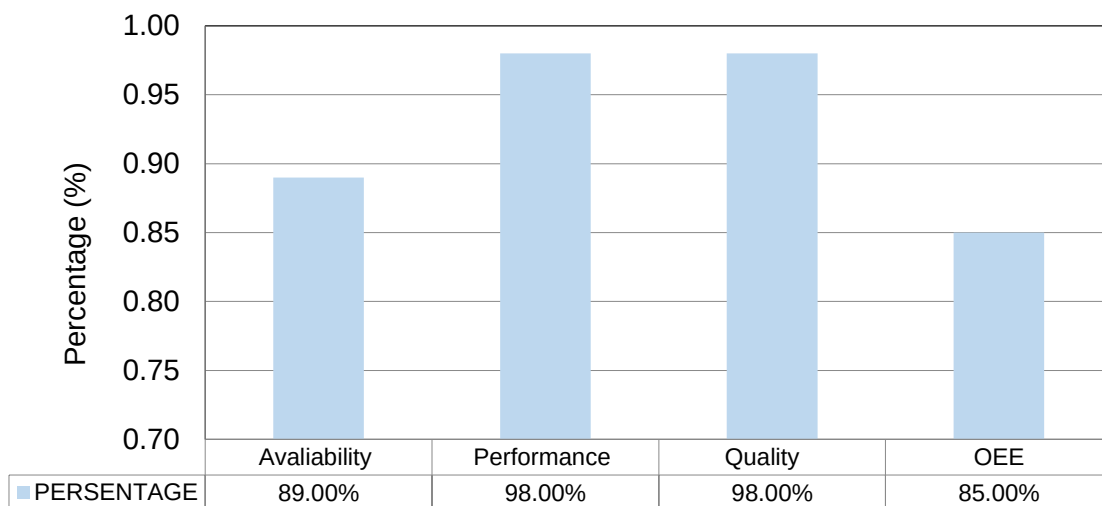


Fig. 12: OEE and its parameters of CPL, 2019, after implementation

Table 10: OEE and its parameters after implementation at 2019

Worksheet 1: OEE and its parameters four month Machines : CPL		
Production Time	Executed Production time (Loading time), hrs	1,605.00
Availability	Time loss (breakdowns, waiting, changeover, line restraints, breaks), hrs	183.66
	Operations time (Running time), hrs	1,421.34
	Availability rate, %	89
Performance	Ideal cycle time × No of parts produced, ton	1,741.47
	Actual output, ton	1,719.98
	Performance rate, %	98
Quality	Total quantity, ton	1,754.30
	Quality losses (Scrap, Rework), ton	34.32

	Good quantity, ton	1,719.98
	Quality rate, %	98
OEE %		85

CONCLUSION

Different techniques for analyzing were implemented in this study such as observations, questionnaire, fishbone diagram, Pareto chart to enable us for proper decision making for recommendations to assist the company to improve the productivity and products reliability. The aim of this research is trying to obtain zero breakdowns, zero defects and zero accidents possibly clearly to improve productivity, save costs by reducing wastes and equipment longevity. Both managers and employees are requested to do significant changes in the regulations rules to enable us for TPM. The poor maintenance and lack the knowledge and training from the employees in this work particularly are the main spots in low productivity. As well, the Effect- Cause diagram analysis revealed the three main effective causes on the breakdown of the production lines are due to the failure and unplanned maintenance, non-ordering inventory and non-organizing maintenance workshop First of all, the higher administrative and employees must make the mutual one team working spirit and then the TPM can be employed. Implementation of TPM is suggested for the CPL in packing machines as case study in the company for short line and later on it was applied for the whole company and others companies in Yemen affiliated to the HSCG. In this paper, TPM has successfully led to the improvement in the machine availability and the downtime, the performance of the machinery and labors and products quality. The value of actual capacity raised from 68 % to 99 %, OEE was jumping form 48 % to 85 %, the total scrap decrease form 3.4 % to 1.99 % and the total downtime decreased from 30.5 % to 11 %. Generally, adoption of TPM system in the YCIC companies has not only provided a comprehensive maintenance system but also motivated the managers and employees for a maximum involvement in order to achieve the ultimate organization's goal. There are a lot of difficulties in implementing of TPM encountered us, such as, typically people who show strong resistance to change, many people consider it just another "program of the month" without paying any interest and also doubting the effectiveness. Insufficient understanding of the methodology and philosophy by middle management, some operators did not get their promotions.

Table 11: TPM planned maintenance actions for packing machine

Components	Failure modes	Root causes	TPM Actions	Period
Sandwich chains	Break biscuits pieces	Pins askew	Change the pins	Weekly
	Deliver failure for biscuits pieces	Delivering timing not adjust, trans. Belt lose	Set the timing of delivering and check the trans. belt	Daily
	Biscuit pieces not consistent	The guides not fixed well	Fixed the guides and make greasing	Daily
	Break biscuits pieces	Machine dirty	Clean the machine	Daily
	No cream on biscuit pieces	Photocell no detect	Adjust the photocell	Weekly
		Photocell not response	Check the connection, check the pulse	Weekly
		Photocell broken	Change the photocell	Quarterly

Components	Failure modes	Root causes	TPM Actions	Period
Vibratos	Not working	Coil burn	Rewind the coil, check and set the load on the card	Monthly
			Check the space between vibratos and its base	Monthly
		Vibrator's controller card fault	Reset the card, repair the fault	Once occur
Safety doors	Machine not work	Doors not close	Close safety doors	Daily
		Limit switch not in correct place	Fix the limit switch in correct position	Daily
		Door's covers broken	Repair the broken covers	Monthly
Figures chains	Break biscuits pieces	The chain not full tighten, no greasing the chain	The chain full tightens and make lubrication	Weekly
Career chains	Not organize the pieces	Pins askew, no greasing the chain	Change damage pins and greasing the chains	Weekly
Cream unit	Cream leaking from scrap	Unit-leaking seals damage or not fixing well	Check the seals, fix it correctly	Weekly
	Cream leaking from pump	The speed between the pump not coordinated	Coordinate the speed between the pumps and scrap	Daily
	Cream leaking form joint	Joint pipe not fix well	Fix the connection joint and make gaskets	Daily
		The component not fixed well	Fixed cream component well	Weekly
Cream mixing pump	Oil and cream leaking form pump	Unti-leaking seals damage	Change unti-leaking seals	Quarterly
Main gearbox	Stranger voice	Gears teeth damage	Change the damage parts	Monthly
	Oil leaking	Reducing oil level	Check oil level, check oil seals	Weekly
	Vibration in machine	Handles damage	Check handles and gears	Biannual
	Motor not work	Inverter fault, overload, motor burn	Check the load, check bearings, lubricate the bearing	Monthly
Cutting and welding	Stranger voice	No lubrication	Lubrication the gears	Monthly
	No heating on packet	Heater damage	Replace the heater	Monthly
		Piston damage	Change piston	Quarterly
		Converter relay damage	Replace the relay	Quarterly
		Short in heating system	Check the connection circuit	Monthly
		Piston pressure low	Check the air source	Daily
		Cutting knife damage	Replace the knife	Monthly
		Cutting knife not adjusted	Adjust the knife	Daily
		Solenoid valve not work	Repair solenoid valve	Monthly

Components	Failure modes	Root causes	TPM Actions	Period
		Temperature sensor damage	Replace new sensor	Yearly
		Air fitting damage	Check and Replace air fitting if needed	Weekly
Person	Careless	No incentive	Reactive the incentive reward	Monthly
	Unqualified	No training	Making training course	Monthly
	Absence	No satisfied of work system	Encourage rage the workers, raise their wage	Yearly
	Leak knowledge	Absence of training program in some field	Increase training program for operators and technicians	Monthly
		Inadequate training program	Provide advance courses to raise skills	Monthly
Workshop	Dirty	Careless, less knowledge	Constantly cleaning, develop people thought 5S tech.	Daily
	Not organize, no sorting	Careless, less knowledge	Appling 5S techniques	Daily
Spare parts	Not available	No plan for request	Making strategic plan for spare part request	Yearly
	Low quality	Fast damage	Check the source of supplier	Monthly
Storing part	Difficult to get part	The place dispersed	Reorganize the store, check from time to time	Monthly
Biscuit size	Make scrap	Not suitable with machine adjusted	Set the size in oven area or reject there	Daily
		Increase or decrease the product weight	Set and fix the pieces size	Daily
Domino printer	No print the date	Sensor loss	Check the sensor	Daily
		Print head block	Clean the head printer	Daily
		No ink and makeup	Add ink and makeup	Daily
		No signal form machine	Check cable sensor	Weekly
		Program faults	Check and repair occur faults	Weekly
		Ink pump burn	Check its circulation and replace damage pump	Monthly
		Ink level sensor fault	Check level sensor and replace it if needed	Weekly
		Short electrical circuit	Check the source of short	Once occur
Production changeover	A lot of scrap	The biscuit size no fix directly	Make trail before operating the line	Weekly

Components	Failure modes	Root causes	TPM Actions	Period
		Machine not adjust	Adjust the machine by simples before operation	Weekly

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