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Enhancing Maintenance Performance through TPM concept:

(A Case on Berehanena selam printing Enterprise)

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Enhancing Maintenance Performance through TPM concept

(A Case Study on Berehanena selam printing Enterprise)

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This is to certify that the thesis prepared by Elisabet Nigussie, entitled: ***"Enhancing Maintenance performance through TPM concept"*** and submitted in partial fulfillments of the requirements for the degree of Master of Science (Mechanical and Industrial Engineering) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Today's industries requires excellent maintenance practices to increase the availability of the machines, to reduce machine downtime and to produce goods with desired quality level. The concept of Total productive maintenance is an approach to improve maintenance performance activities with the aim in maximizes equipment effectiveness through all the participation from top management to shop floor workers. The main objective of the research is to propose TPM framework that improve the maintenance performance of the company. In order to do this the study carried out the significant impact of TPM critical success factors towards maintenance performance. Data relevant to the research was collected using designed questionnaires, informal interviews, direct observations and company records. In order to analyze the collected data from primary and secondary sources, the researcher has used different tools such as OEE, SPSS software and cause and effect diagram. The finding from the result obtained from the correlation and regression analysis reveals that the critical success factors such as organizational factors, human factors, technological factors and resource factors has a positive significant impact in affecting the maintenance performance of the company. With respect to the highest significant, human factors contributes greater in affecting the maintenance performance from all the CSF. The researchers then selected TPM pillars that can address the critical success factor which has a significant impact in affecting maintenance of the company and proposed TPM implementation framework including with the action plan for each pillars that are going to practice.

***Key words**: Total Productive Maintenance, Critical Success Factors, Overall Equipment Effectiveness, Maintenance Performance, TPM pillars.*

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ACRONYMS

BSPE - Berhanena Selam Printing Enterprise

TPM – Total Productive Maintenance

RCM – Reliability Centered Maintenance

CSF – Critical success Factor

OF – Organizational factor

HF – Human factor

TF – Technological factor

RF – Resource factor

MP – Maintenance performance

OEE - Overall equipment effectiveness

WCM - World class manufacturing

WCP - World class performance

FMEA - Failure modes and effects analysis

SPSS – Statistical package for the social science

MTBF – Mean time to Failure

MTTR – Mean time to repair

CHAPTER ONE

INTRODUCTION

1.1. Background and Justification

The survival of companies are depends on their ability to rapidly innovate and improve to compete in the local and global market accordingly, industries must start reviewing their methods, systems and others ways that they are using and try to modify through continuous improvement to sustain in the business. In any manufacturing company there are different types of equipment's in the production system, in order to guarantee the stable process as planned all equipment's must have high availability and reliability. Here in this regards the maintenance department is responsible for keeping all the equipment's in a good condition. It's very known that maintenance costs and accidental breakdowns are a great impact on the profitability of the company hence; companies must start to work with maintenance as a center point of profit. In today's trend to improve the performance of organizations, various business management strategies have been developed.

TPM is one approach to improve the performance of maintenance activities of manufacturing system (Okpala et al., 2018). The concept of Total Productive Maintenance has been widely accepted, it's a composition of maintaining with newly defined concept and improving the integrity of production and quality through the machines, equipment, process and employees that adds the value to the industry (Virupakshar & Badiger, 2016). TPM program changes the industry maintenance policy cultures through participation of all employees' towards the maintenance system of the company. Modem manufacturing requires that to be successful, organizations must be supported by both effective and efficient maintenance practices and procedures. TPM has been widely known as a strategic weapon used in manufacturing improvement and takes all the advantages of knowledge and skill from all individuals in an organization to achieve organizational performance. It's an essential strategic program to meet customers demand, quality and lead times (on time delivery) with the aim to create a culture that operator to feel ownership of the machines that they are operated and to develop skilled operators that diagnosis/ maintain his/her equipment's.

Accordingly the research focuses on BEHANENA SELAM PRINTING ENTERPRISE taking as a case company. Due to the reason that the company is one of the largest printing companies and

the role of the company in printing services extended from printing books and magazines to advanced security printing activities. The enterprise has been playing the leading role in printing industry in Ethiopia for more than 90 years. However, it is observed that as a result of a poorly integrated maintenance system, the company had been experiencing high rate of equipment breakdowns and prolonged downtime. This reduced equipment utilization and maintenance performance. Due to high rate of unplanned breakdowns/failures manufacturing industries operates less than their designed capacity; this is mostly seen in our country Ethiopia. In view of the changes in equipment's technical complexity and accidental failures consequences, there should be assigning of a new aspect of maintenance activity. The importance of maintenance functions has increased due to its role in keeping and improving the availability, product quality, productivity and safety requirements.

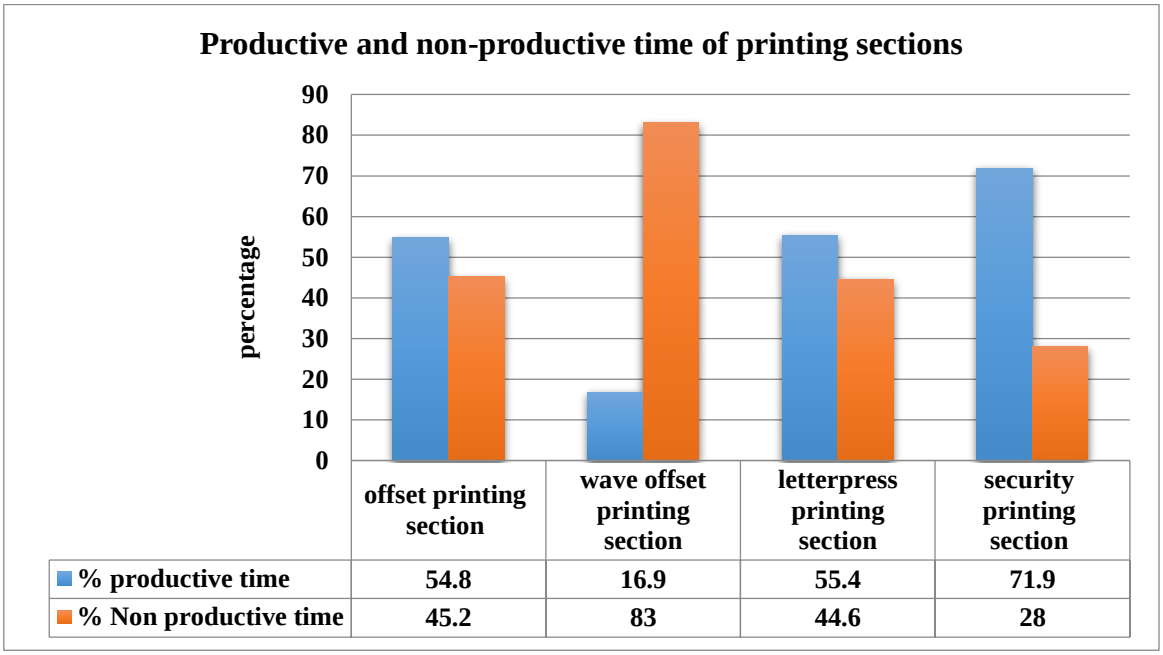
Business environment becoming considerably complex and challenging, organizations are under pressure to continuously enhance their capabilities and compete effectively. In this regards printing technology is evolving rapidly, this means the technology complexity will get higher and needs organizations attentions in keeping the equipment effectively through a well-developed maintenance systems since maintenance is considered as key to improving the company's maintenance performance to overcome prolonged downtimes due to high equipment failures. Therefore, as the country is having high demand of printing products, enhancing the maintenance performance of the industry using of different tools and techniques like TPM concepts, TPM is one approach to improve performance of maintenance activities through involvement of production and maintenance staff working together. This will help the industry to efficient way of maintaining machineries besides that it also contributes an experience for other industries.

1.2. Statement of the problem

In business environment in order to reach high performance and productivity of a manufacturing system it is essential to develop new strategies and react quickly to remain competitive. Attaining reliability and availability of equipment's is very important for industries having high maintenance related problems.

Berhanena Selam Printing Enterprise (BSPE) is the leading Printing Industry in the country engaged in delivering most of printing services for more than 90 years. The role of the company in printing services extended from printing books and magazines to advanced security printing activities. In the company there are around 150 different old and new printing machineries, from those only 90 of the machines are working the remaining machines are not working due to spare part availability and age. From the data found from the company report in the year 2017/2018 the amount of production planned in birr (ETB) of different printing products such as newspaper, books, magazine, secret printing, different publications and Writing/tools was 397,793,779 ETB but the actual amount registered was 238,676,267.4 ETB, this indicates the company only met 60% of the plan. However, it is observed that the company has been experiencing high rate of equipment breakdowns and prolonged downtime due to poor maintenance system. As per the company report found regarding to the planned production time and the downtime that was registered due to machine breakdowns in year 2017/2018 of the four printing sections:

- In offset printing section from the planned production time 26,271.5 hr, the downtime registered due to accidental machine breakdown was 11,878.52 hr.
- In wave offset printing section from the planned production time 12,360 hr, the downtime registered due to accidental machine breakdown was 10,264.91hr.
- In letterpress printing section from the planned production time 21,630 hr, the downtime registered due to accidental machine breakdown was 9,644.93 hr and
- In security printing section from the planned production time 40,463.25 hr, the downtime registered due to accidental machine breakdown was 11,335.49 hr.



	offset printing section	wave offset printing section	letterpress printing section	security printing section
% productive time	54.8	16.9	55.4	71.9
% Non productive time	45.2	83	44.6	28

Figure 1.1: productive and non-productive time of printing sections (source: company report)

As per the figure 1.1 above the productive and non-productive time of printing sections are presented accordingly, the productive time in offset, wave offset, letterpress and security printing section was 54.8%, 16.9%, 55.4% and 71.9% respectively. With respect to the non-productive time in offset, wave offset, letterpress and security printing section was 45.2%, 83%, 44.6% and 28% respectively. The values indicated that due to high equipment failures there is high equipment's downtime occurrence in the company that leads interruption of the planned production schedules and leads to loss meeting the printing demand, on time delivery for the customers, productivity, customer satisfaction, efficiency & ability to compete against global industry. Therefore, occurrence of repetitive equipment failures and prolonged downtime is a clear sign of poor maintenance performance.

This research focuses in enhancing of maintenance performance of the company through Total productive maintenance (TPM) concepts by identifying the critical factors that has impact in affecting maintenance performance of the company.

1.3. Research Questions

- What are the factors that hinder maintenance performance of the company?
- What is the relationship between TPM critical success factors and maintenance performance?

- How to enhance the maintenance performance of the company through TPM?

1.4. Research Objectives

General Objectives

The general aim of this research is to propose TPM framework that improve maintenance performance of the company.

Specific objectives

The specific objectives of the study are:

- To identify factors that affect maintenance performance of the company.
- To investigate the relationship between TPM critical success factors and maintenance performance.
- To identify the critical success factors that has strong significant impact in affecting the maintenance performance.
- To propose TPM framework that improve maintenance performance of the company.

1.5. Significance of the Research

TPM is the most well-known programs that different researchers have been approved. Its role goes beyond machine availability to factor in all issues related to equipment performance through involvement of both technical and human aspects. Accordingly the researcher believes that this study have a significant endless role for the country that have still thinking of maintenance is a cost center activity. Due to the reason that the framework proposed is based on the CSFs that are selected considering the company condition, the framework can be compatible with Ethiopian industries in order to improve the sector's maintenance performance. Besides the roles for manufacturing industries in the country, this study could be used as an input for researchers who want to study further in the future.

1.6. Scope of the Research

The researcher mainly focused in investigating impact of maintenance performance from different perspective of TPM CSFs which are organizational, human, technology and resource aspects only. In regards to machine condition analysis, the case company has three divisions, pre-printing, printing and post printing. Due to the reasons that there is a low occurrence of

machine failures in the pre-printing and post printing division, the researcher excludes machines that are found in this division for further analysis.

1.7. Organization of the Research

The research consists seven chapters. The first chapter is the Introduction part and it discusses the background and justification of the study, statement of the problem, research objective, and significance of the research and scope of the research. The second chapter addresses definitions and theoretical and empirical review of related literature of the study. The third chapter provides methodology of the research. Chapter four discusses the overview of the case company. Fifth chapter Data presentation and discussion are discussed. In chapter six the proposed TPM framework is presented and chapter seven covers the conclusion and recommendations of the study and future research directions.

CHAPTER TWO

LITERATURE REVIEW

To gain understanding about the role of various maintenance concepts, maintenance trends presented by different researchers and create strong foundation, the research work begun with an extensive literature study. Considering the research title the literature review method categorized into three areas which are TPM related, maintenance related and maintenance and performance related researches this is due to the reason that to find out how far researchers had done in those areas. Different search engines have been used like research gate, Google scholar, Elsevier and others to get researches which had done in those selected areas. Regarding those three areas different types of researches like journals, articles, thesis, and conference papers were used.

Based on the search engines the researchers was limited in the number of literatures to be reviewed and focused more of the researches that have done from 2012 up to now, this is the reason that to get most recent information's regarding to the research titles. Accordingly, 192 different researches have been reviewed; out of this 100 of papers are TPM related researches. Here in the figure2.1 below shows that the percentage covered by each category TPM related, maintenance related and maintenance and performance related researches.

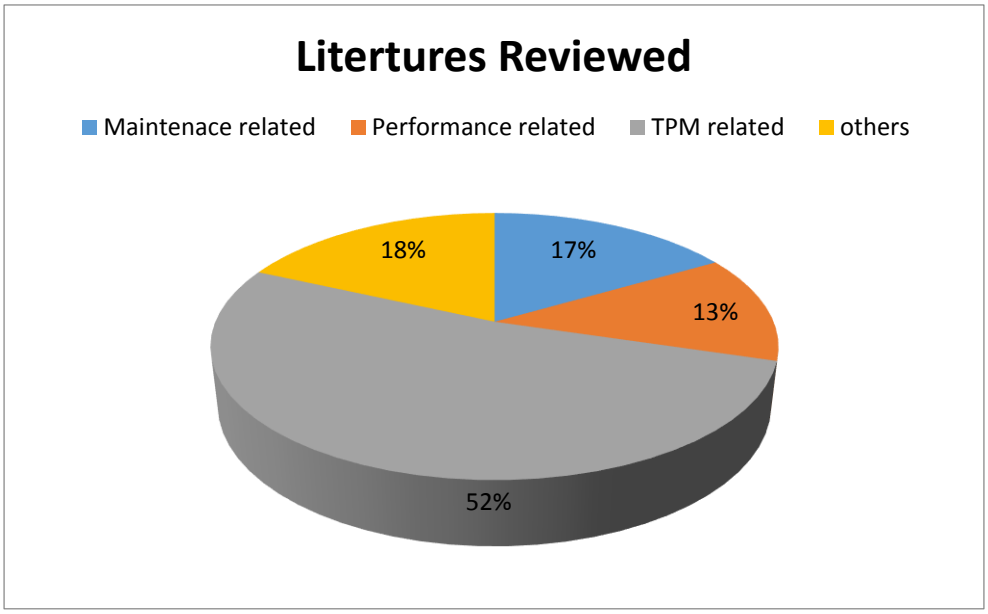


Figure 2.1: Literature reviewed

2.1. Definition of Terms

Several international scholars and organizations give different definitions and meanings of maintenance, TPM and performance.

Maintenance

According to (Eyoh, J. and Kalawsky, 2018) maintenance is defined basically be seen as a function to keep a tool, machine, or system (simple or complex), in a working condition by proper usage, repairing broken part or component, or replacing some of the broken parts such that it is available and fit for the designed purpose whenever the need arises.

As (Chandrahas, 2015) maintenance is defined as the combination of all technical and administrative actions, including supervision and action indented to retain the machine or restore it to a state in which it can perform a required function.

Even if researchers defines Maintenance in different ways, its main purposes is too reduce breakdowns and to increase availability. Maintenance must be recognized as an integral part of the plant production strategy in order to make its proper contribution to profits, productivity, and quality (Desta et al., 2015). It has to be so considered that as a unique business process. It requires an approach that is different from other business.

TPM

According to (Nallusamy & Majumdar, 2017) stated that the fundamental concept of TPM is, if you properly maintain plant machinery there will be a sharp decline in machine breakdowns, safety and quality problems

As (Virupakshar & Badiger, 2016) Total Productive Maintenance is a composition of maintaining with newly defined concept and improving the integrity of production and quality through the machines, equipment, process and employees that adds the value to the industry.

According to (Kumar et al., 2017) Total Productive maintenance is an expansion of lean manufacturing system.

From the study by (Venkateswaran, 2017) TPM is an evolving technique which is followed in the all organization. This helps improve key business process which helps firms to identify key performance indicators.

Performance

According (R. Peach, 2016) (Dwight, 1999) performance defined as "the level to which a goal is attained".

2.2. Evolution of Maintenance

In the past maintenance was considered as more a cost center than a profit center. It was nothing and considered as evil. Industries did not have a high mechanical level before the Second World War, that is, most of the equipment was over-designed and simple (Fredrikssom, 2012). Machine and equipment designers did not consider the issue of maintainability in the course of designing these simple, mechanical systems (Eyoh, J. and Kalawsky, 2018). The industrial equipment was running until failure occurred, and when it did it was either replaced or repaired. Thus the mentality was: "fix it when it breaks" (Fredrikssom, 2012).

During Second World War the need for sophisticated and complex production system paved the way for industrial and technological revolution (Eyoh, J. and Kalawsky, 2018). The war drastically changes the situations and there was obvious pressure for high quality products and services of all types, especially in department of defense and energy sector. This situation forced the industrialist to reluctantly and weakly integrate maintenance concept with production operations (Eyoh, J. and Kalawsky, 2018).

Maintenance strategies have significantly evolved during the last 50 years progressing from breakdowns to preventive, predictive, then pro-active and synergic approach (Patidar, Soni, & Soni, 2017). An increasingly number of companies replaces the current reactive, fire-fighting, maintenance strategy with proactive strategies such as predictive and preventive maintenance and also with aggressive strategies such as Total Productive Maintenance (TPM) in order to achieve world-class performance (Fredrikssom, 2012). As (Maletic et al., 2014) stated several maintenance approaches, i.e. strategies and concepts, have been developed and implemented through the evolution of maintenance.

2.3. Maintenance Strategies and Development

Maintenance strategy defined Management method used in order to achieve the maintenance objectives which are the targets assigned to or accepted by the management and maintenance

department, these targets may include availability, cost reduction, product quality, environment preservation, safety. (Fredrikssom, 2012) (prEN 13306, 1998).

This day in order to be competitive in the market industries forced to increase production efficiency continuously. To do so maintenance of production equipment is one of the important factors to be focused on. As (Shahin, 2014) stated that effective maintenance is critical to many operations. It extends equipment life, improves equipment availability and retains equipment in proper condition. Conversely, poorly maintained equipment may lead to more frequent equipment failures, poor utilization of equipment and delayed production schedules. The role of maintenance strategy is very important in all kind of manufacturing industries. Each maintenance strategy has their characteristics, importance and drawbacks (Chandrahas, 2015). Selection of maintenance strategy has to be varying from one machine to another due to their characteristics and purposes. Using of inappropriate maintenance strategy may increase the maintenance cost and this will increase the production cost (Chandrahas, 2015). Maintenance strategy provides critical support for heavy and capital-intensive industries by keeping the productivity performance of plants and machineries in a reliable and safe operating condition (Patidar et al., 2017) (Parida et.al, 2015). From history maintenance has passed through several major developments in the table2.1 below it shows the development maintenance strategies:

Table2.0.1: Maintenance Techniques Development (Patidar et al., 2017) (Deshpande et al., 2002)(Garg et al., 2006)(Kaur et al., 2012)(Parida et al., 2007)(Sharma et al., 2011) (Willmott, 1994)

Generation (Period)	Techniques	Strategy	Characteristics
First (1940s, 1950s)	Breakdown Maintenance	Breakdown	No budget constraints, Fix at Fail
Second(1960s,1970s)	Planned Preventive	Preventive	Periodic part inspection or Replacement
Third (1980s, 1990s,2000)	Condition Based Maintenance	Predictive	Health trend monitoring and prognosis
Third (1980s, 1990s,2000)	Reliability centered Maintenance	Predictive/ Pro-active	Design for Reliability and maintainability
Third (1980s, 1990s,2000)	Total Productive Maintenance	Pro-active (Holistic)	The way for Zero – Defects / Accidents/ Breakdowns.

Fourth (2000, 2010s,2015)	TPM integrating with lean tools (like TQM,VSM, JIT, CI, etc.)	Synergic Approach/ Integrated Practices	The way for continuous improvement and preparing Self need based model in manufacturing industries.

In the above table under the evolution of maintenance, different maintenance strategies had been developed and the characteristics of each maintenance strategy summarized.

The maintenance strategies explained below one by one:

Breakdown Maintenance

This type of maintenance was introduced in the 1950s and it is called run to failure. The basic philosophy is allowing machinery to run to failure and repair or replace damaged equipment when obvious problems occur (Mekasha, 2018).

Preventive Maintenance (PM)

PM was begun in the 1959s. Its aim is to prevent the occurrence of damage equipments through regular basis maintenance activities to extend the equipment life.

According to European standard PM defined Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item (Fredrikssom, 2012)(prEN 13306, 1998).

Based on the European standard (prEN 13306, 1998) Preventive maintenance divided into three divisions (Fredrikssom, 2012) :

Scheduled Maintenance

Preventive maintenance carried out in accordance with an established time schedule or established number of units of use.

Predetermined Maintenance

Preventive maintenance carried out without previously condition investigations and in accordance with established intervals of time or number of units of use.

Condition Based Maintenance

Preventive maintenance consists of performance, parameter monitoring and subsequent actions. The performance and parameter monitoring may be scheduled, on request or continuously.

Predictive Maintenance

Often referred to as condition Based Maintenance. Maintenance of this type is characterized by the use of advanced techniques, sensors, including probability statistics to detect the appearance of signs of failure / decline in function. Predictive Maintenance is used only on systems that will cause serious problems in case of damage to the machine or to dangerous processes (Herry et al., 2018).

Reliability Centered Maintenance (RCM)

Reliability Centered Maintenance originated in the Airline industry in the 1960's. RCM is a method to determine maintenance task to ensure the reliability of a system. It serves to overcome the dominant cause of failure which will bring on maintenance decisions that focus on the prevention of these types of failures that occur often (Kumar Sharma & Gopal Sharma, 2014)

An RCM process identifies all of the assets functions and functional failures, and its reasonably likely failure modes or failure causes. Reliability-Centered Maintenance (RCM) integrates Preventive Maintenance (PM), Predictive Testing and Inspection (PT&I), Repair (also called reactive maintenance), and Proactive Maintenance to increase the probability that a machine or component will function in the required manner over its design life-cycle with a minimum amount of maintenance and downtime (NASA, 2008).

Analysis of RCM is based on calculations of the probabilities of failures and detailed failure modes and effects analysis (FMEA). The RCM analysis is used to determine appropriate maintenance tasks to address each of the identified failure modes and their consequences.

The RCM analysis carefully considers the following questions:

- What does the system or equipment do; what is its function?
- What functional failures are likely to occur?
- What are the likely consequences of these functional failures?
- What can be done to reduce the probability of the failure, identify the onset of failure, or reduce the consequences of the failure?

Total Productive Maintenance (TPM)

The concept of Total productive maintenance (TPM) was introduced in 1971, in Japan, to solve maintenance problems of systems by giving operators and employees more responsibility (Pascal et al., 2019) (Nakajima, 1984). As the name TPM suggests with three words, Total: signifies to consider every aspect and involving everybody from top to bottom; Productive: emphasis on

trying to do it while production goes on and minimize troubles for production; and Maintenance: means equipment upkeep autonomously by production operators in good condition repair, clean, grease, and accept to spend necessary time on it (Patidar et al., 2017)(Ahuja et.al 2007). TPM is a production-driven improvement methodology that uses involvement of employees, linking manufacturing, maintenance and engineering, to optimize and guarantee equipment's or plant assets. As (Oleghe & Salonitis, 2019), TPM as a whole easily fits into this definition. It consists of tasks, resources, decisions, people, information processing, ill-structured problems and many other parts that work in unison to create a complex and dynamic whole.

As (Kumar Aroor et al., 2015) Total Productive maintenance (TPM) is a well-defined innovative Japanese concept for maintaining plant and equipment. It can be consider as science of machinery and plant health. TPM as a relatively new but very effective process that led to better maintenance and upkeep of the equipment's resulted in enhanced reliability of equipment's and quality of products (Patidar et al., 2017) (Kumar et al., 2014).

TPM has become a new management tool in all types of industrial organizations. In recent time, (Patil et al., 2018a) many industrial organizations have proved that significant improvements in organizations can be obtained through TPM. If it is effectively employed considering improvement of manufacturing efficiency, it leads the industry highly competitive. TPM is expected to prove as an efficient policy for contributing the industrial units a consistent improvement of performance in achieving core competencies. So, in the highly competitive environment, TPM may prove to be the best among the proactive initiatives that can help the industrial organizations to score new heights of attainments (Patil et al., 2018a).

In the figure2.2 below, it shows TPM evolutions

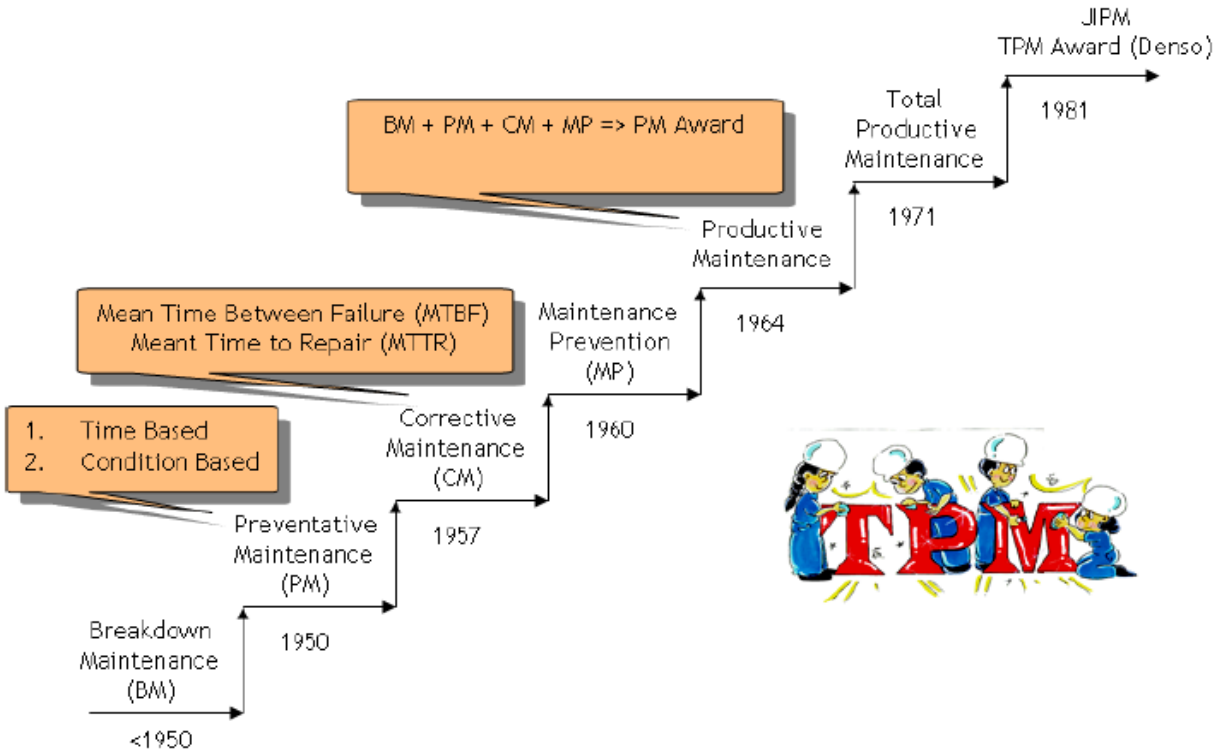


Figure2.2: History of TPM (Mey, 2011)(Technology Promotion Association, 2002)

Different philosophers define TPM in different ways, here are some definitions mentioned in the study by (Sharma et al., 2012).

Table2.0.2: Various philosophies of TPM (Sharma et al., 2012)

Philosopher	Year	Definition / Philosophy
Thomas R. Pomorski	2004	Total Productive Manufacturing is a structured equipment-centric continuous improvement process that strives to optimize production effectiveness by identifying and eliminating equipment and production efficiency losses throughout the production system life cycle through active team based participation of employees across all levels of the operational hierarchy.
(Cooke)	2000	TPM is intended to "bring both functions (production and maintenance) together by a combination of good working practices, team working, and continuous improvement.
(Lawrence)	1999	TPM is the general movement on the part of businesses to try to do more with less.
(McKone et al.)	1999	TPM is a program that "addresses equipment maintenance through a comprehensive productive-maintenance delivery system covering the entire life of the equipment and involving all employees from production and maintenance personnel to top management".
(Blanchard)	1997	TPM is "an integrated life-cycle approach to factory maintenance and support

(SME)	1995	TPM is "a way of working together to improve equipment effectiveness".
(SME)	1995	TPM is a methodology and philosophy of strategic equipment management focused on the goal of building product quality by maximizing equipment effectiveness. It embraces the concept of continuous improvement and total participation by all employees and by all departments.
(Robinson and Ginder)	1995	TPM is a production-driven improvement methodology that is designed to optimize equipment reliability and ensure efficient management of plant assets.
(Robinson and Ginder)	1995	TPM is a method for bringing about change. It is a set of structured activities that can lead to improved management of plant assets when properly performed by individuals and teams.
(Steinbacher and Steinbacher)	1993	TPM is "all of the strategies needed to sustain a healthy maintenance log.

The researchers tried to identify different researchers in the above table2.2 that define TPM and as per the review; TPM is strategies that acquire involvement of all individuals in the organization to achieve organizational goal and objectives through efficient equipment's.

2.4. Pillars of Total Productive Maintenance (TPM)

There are various pillars that TPM has built. Initially formulated with five pillars, the present day structure of TPM is built on eight pillars (Sugumaran et al., 2014)(Ahuja et al., 2008). It covers all the operations of the company: production, maintenance, quality, safety, environment, health, projects, planning, and admin offices.

Researchers have established that the eight pillars of TPM formed the foundation to achieve world class performance (WCP) by the organizations (Sugumaran et al., 2014) (Ahuja et al., 2008).

These eight pillars of TPM are listed below (Sugumaran et al., 2014):

Pillar 1: Autonomous maintenance

It is an operator's responsibility for carrying out basic maintenance of equipment. The routine maintenance that takes place by the operators includes cleaning, lubricating and inspection. In the process of creating responsibility of operators in carrying routine maintenance, train the workers and build their capability to be multi skilled, self-directed is a must. By doing this the gap between production workers and maintenance staffs will be closed. This makes the works to be easier and create one team.

Giving the responsibility of the routine maintenance for the operators will create greater ownership of their equipment's, increase knowledge's of operators regarding the equipment's that they operated and easily identifies any issues before it occurs and becomes failure.

According to (Bhoyar et al., 2017) the following seven steps are implemented to progressively increase operators knowledge, participation and responsibility for their equipment.

- Perform initial cleaning and inspection
- Countermeasures for the causes and effects of dirt and dust
- Establish cleaning and lubrication standards
- Conduct general inspection training
- Carry out equipment inspection checks
- Workplace management and control
- Continuous improvement

Pillar 2: Planned maintenance

It is an establishment of a planned maintenance (predictive, preventive and productive maintenance) system to increase maintenance efficiency.

The following seven steps are implemented under the planned maintenance (Bhoyar et al., 2017).

- Correct operation
- Correct set-up
- Cleaning
- Lubrication
- Retightening
- Feedback and repair of minor defects
- Quality spare parts

Pillar 3: Focused improvement

This is all about Identify; manage organization wide loss management system and Maximize efficiency by eliminating waste and manufacturing losses. Manufacturing losses are categorized into 3 big losses:

- Equipment losses
- Manpower losses
- Material losses

Under these three categories of losses, the followings are losses included to each manufacturing losses:

Figure2.3: Manufacturing losses (Bhoyar et al., 2017)

Pillar 4: Quality maintenance

It is designed for building zero defect system in the company through error detection and prevention of production processes. To eliminate frequent sources of quality defects, root cause analysis applies. Its target is on identifying the parameters of machine those affect the product quality and improvement through focusing on root sources of defect removal and reducing number of defect occurrences.

Pillar 5: Education and Training

It's about creating skill and training plan to support the TPM implementation. It applies to operators, maintenance personnel and managers. Operators develop skills to routinely maintain equipment and identify emerging problems. Maintenance personnel learn techniques for proactive and preventative maintenance. Managers are trained on TPM principles as well as on employee coaching and development. This pillar aims is in development of trained operators to

increase their ability and makes operators to solve the existed problems at the sources. The purpose of this pillar is to create a plant full of skilled employees. Training policy targets on improvement of knowledge and skill.

According to (Sharma et al., 2012) education and training is an essential activity in the process of implementation of TPM, since, the effectiveness of whole programme depends on the degree to which the employees comprehend it and acquire desired operations and maintenance skills.

Pillar 6: Safety, health and environment

This is about building safety and health environment system in the company. It maintains a safe and healthy working environment. It eliminates potential health and safety risks, resulting in a safer workplace and specifically targets the goal of an accident-free workplace.

Pillar 7: Office TPM

This pillar concentrates on all areas that provide administrative and supporting functions in the organization. For its effective implementation TPM must embrace the entire company, including manufacturing support functions, administrative and support departments.

Pillar 8: Development management

This pillar describes the methodology on how to produce new products and new arrangements at a very short time and at lowest cost (Patil et al., 2018a). During the development process of new machine or the new product, each steps, tools and techniques has to be clearly defined.

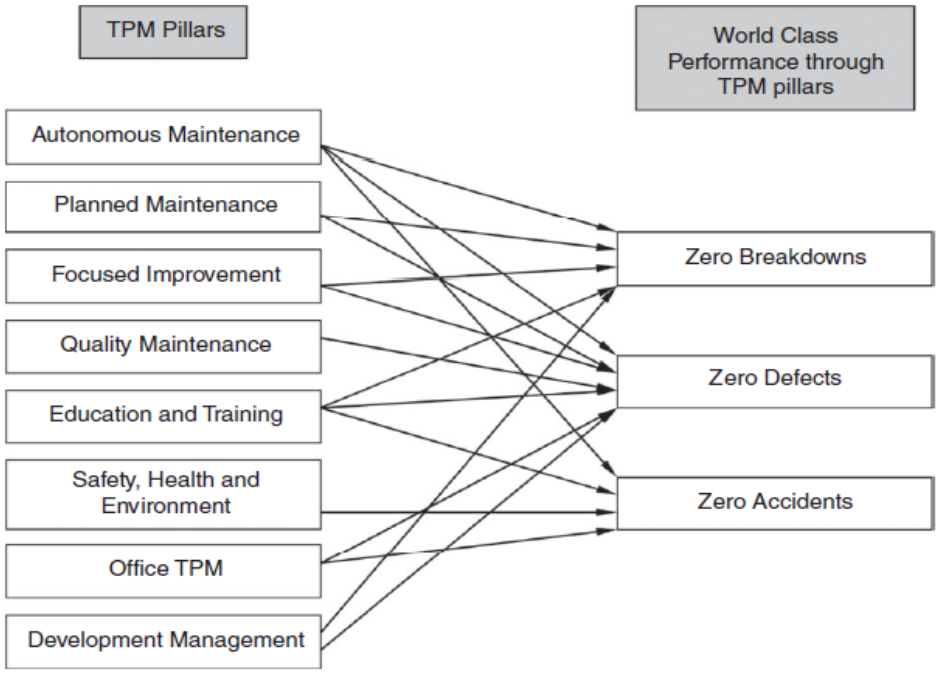


Figure2.4: TPM pillars and their role in achieving value addition in organizations (Sivaram et al., 2014)

2.5. Why TPM?

Due to high competitive environment, organizations must possess both efficient maintenance and effective manufacturing strategies to be successful and achieve world-class-manufacturing. The survival of companies are depends on their ability to rapidly innovate and improve. As a result there is a search for methods and techniques that drive improvements in performance and productivity. TPM is one important approach to adopt by either large organization or SMEs to improve the performance of maintenance activities (Abhishek Jain, 2018) (Ahuja, I. P. S., and Kumar, 2009).

With advancements in technology manufacturing firms has to revise and change the way that they are doing through different tools and techniques, for this matter TPM is a one such standard philosophy, which emphasizes proactive and preventative maintenance to maximize the operational efficiency of equipment (Kumar Aroor et al., 2015). The concepts of Total Productive Maintenance (TPM) helping firms to maximize the equipment effectiveness till the expiry of the equipment. Maintaining equipment throughout its lifetime requires larger amount of time effort. TPM helps organizations in maintaining equipment to protect from quality

defects, speed losses and also prevent unexpected breakdown because of accidental and incidental losses (Venkateswaran, 2017).

As (Okpala et al., 2018) mentioned TPM builds a close relationship between maintenance and productivity, showing that good care and up-keep of equipment will result in higher productivity. It involves production and maintenance staff working together as a team to reduce wastage, minimize downtime toward improving the end-product quality (Bakri et al., 2012)(Eti et al., 2004). In the past the perception of maintenances role was get into action whenever a breakdown occurred but TPM can shift the traditional maintenance systems from being reactive to being more reactive through maintaining the equipment's in optimum conditions at all times. Total Productive Maintenance (TPM) provides a continuous, life cycle approach, to equipment management system that minimizes equipment failures, production defects, wastages, and accidents (Kumar Aroor et al., 2015). It helps to improve the number of things in the organization in term of employee's skill, moralities, ethnic changes, machine condition, maintenance, and operation integration (Rajdeep Singh, 2017).

Accordingly TPM is the selected tools in this research due to the reason that TPM is a very well-known strategy that improves performance of maintenance activities through involvement of all the production and maintenance staffs.

2.6. Maintenance Trend Globally

Maintenance has traditionally been viewed as a separate entity outside of the manufacturing process. As companies began to identify the role of maintenance in the production process a gradual shift in thinking occurred (R.S. Velmurugan and Tarun Dhingra, 2015). Maintenance today contributes to the aim of sustainable development in society, including environmental and energy saving aspects, safety aspects and economical aspects (Starr et al., 2010). Many of the world's leading experts claim that the technological development in ICT is exponential growth. Humanity rapidly multiply the amount of data generated (Miroslav FUSKO, 2016).

High equipment availability and high performance can be achieved through effective and efficient equipment maintenance programs. It extends equipment life, improves equipment availability and retains equipment in proper condition (Maletic et al., 2014). The reliability and

availability of machines and instruments are crucial factors of competitiveness, particularly in applications where safety and availability are important (Starr et al., 2010).

Today as technology is rapidly integrated elsewhere in organizations, many maintenance departments are just now implementing PCs and related technology, like CMMS software (Miroslav FUSKO, 2016). Higher reliability of industrial plants and machines means fewer risks, both personal and environmental, and better control, as well as energy conservation and lower expenses during the operating lifetime (Starr et al., 2010).

The international competitiveness of the industry can be improved by developing new techniques and methods to specify and control the product reliability more precisely and convincingly (Starr et al., 2010). Today, though, things are rapidly changing in the maintenance office. Smart, proactive maintenance managers are taking advantage of modern technologies to forecast, manage, and monitor maintenance activities (Miroslav FUSKO, 2016). Manufacturing industries has practiced change due to process, product, customer expectations, suppliers and competitiveness.

2.7. Maintenance Trend in Ethiopia

Over the past two to three decades, maintenance management has undergone a paradigm shift; it is no longer seen as a necessary evil, but as an integral part of the business process that creates value for the organization (R. Peach, 2016). However, in Ethiopia still that thinking exists. As (Lemma et al., 2013) mentioned in their study most of Ethiopian industries maintenance is considered as a necessary evil activity. Status of maintenance in industries is unknown beside there is no organized body that works on maintenance and the practice of maintenance still in an infant stage in the country (Mekasha, 2018).

Mostly manufacturing industries operates less than their designed capacity and the reason behind could be many but high rate of unplanned breakdowns is one of the main issues, this is clearly seen in our country. Considering industries performance there is believe that once a company is profitable, they thinks that the company is performing well. Doing the maintenance activities based on plan and proactively before breakdown occurred considered as costly. Majority of manufacturing industries in Ethiopia considered maintenance as a cost center instead a profit generating function but the reality is reveres that maintenance is not a cost center; it’s a profit generating function. Inadequate plan maintenance is linked with low productivity, downtime

poor machine performance this will leads in reduction of production, increasing costs, and lower profits.

Most of manufacturing industries in Ethiopia don't try to use appropriate decision techniques in order to reveals costs associated with production losses, reduced equipment downtime and machine performance that are hidden. According to (Chandrahas, 2015), performance of a machine depends on the type of maintenance strategies employed on it. Manufacturing industries has to consider proper maintenance strategies for their machines because machine failures can cause production loss.

As (Meseret, 2007), mentioned most organizations in Ethiopia lack efficient maintenance management system that affects the total output. Maintenance has received little notice in most organization, which makes the availability of the machines to low and this directly affects the productivity of the organization. The main problems that have seen in manufacturing industries are there is no suitable action to keep machine performance and extend the life cycle of the machines. Different types of maintenance alternatives have been proposed to achieve the ultimate goal. However, a maintenance policy implemented in a similar machine but in different manufacturing environments the situation varies and may not produce similar results because of various operating factors such as humidity, temperature and work load.

Maintenance should not always be reactive instead it should be proactive for this matter maintenance activities have to be executed more effectively. When maintenances activities are properly executed it will maximize the performance and availability of the machines this will lead productivity to be increased. In recent times due to the role maintenance in ensuring and improving availability of machines, efficiency of performance, quality of product and other, its impact on business performance aspects such as productivity and profitability has increased.

Currently it's clearly seen in our country that most of the industries pay a little attentions or no attention at all in measuring performance and productivity. Due to this things that have to be improved cannot be revealed it goes to be hidden. Even if researchers proposed different studies that maintenance is one of the most important areas in the business environment that companies to consider but still nothing has been happened. According to (Lemma et al., 2013) mentioned that the concept of TPM in Ethiopian manufacturing industries is the critical missing concepts

in successfully achieving not only world class equipment performance, but also it is a powerful new means in improving overall industry performance. This means a lot more have to be done in creating awareness for the industries to change their attitudes about maintenance.

2.8. Maintenance in Printing Industry

Among organization good maintenance practice is necessary in order to increase productivity and profits. This is an important issues due to that there is a clear link between productivity, reliability and maintenance. In the printing industry effective maintenance is essential to guarantee that the optimum performance of equipment is sustained and productivity is reliable. The newspaper printing industry is unique in that its products must be made "just-in-time" and has a very short shelf life. According to (Csaba Horvath, 2010) rapid technological and economic changes are setting radically new task for maintenance divisions of printing works. These days the technology of printing in the world goes far and required good attention.

Effective maintenance can reduce total operating costs, produce finished work on time and ensure consistent product quality. However, many organizations in Ethiopia are still reactive in their approach to maintenance and so only focus on equipment when a breakdown occurs.

2.9. Role of Maintenance in Manufacturing Performance Improvement

As (R.S. Velmurugan and Tarun Dhingra, 2015) mentioned in their study, Maintenance is not just ensuring healthiness of equipment in a facility but it also plays a crucial role in achieving organization's goals and objectives with optimum maintenance cost and maximum production. The key objective of maintenance management is "total asset life cycle optimization" i.e., maximization of availability of plant/equipment and reliability of these assets in order to achieve operational/business objectives. Therefore, maintenance is not only dealing with technology issues and it is a mix of management, operations, technology and business strategies(R.S. Velmurugan and Tarun Dhingra, 2015)(Pintelon et al., 2008).

Maintenance has been largely considered as a support function which is non -productive since it does not generate cash directly (Mwanza & Mbohwa, 2015). But in modern management Maintenance is one of the areas to be given due consideration to increase machine productivity and to produce quality products as well (Lemma et al., 2013). To survive in this high global

competition, organization ability depends on how well the organization adapts the market demand due to a market changing environment that to satisfy the customers. Performance and competitiveness of manufacturing companies is relying on the availability, reliability and productivity of their production facilities. This means to achieve competitiveness, an organization has to consider and manages factors like reliability, quality, flexibility, ability to meet demand and delivery. Beside in addition to maintenance management other departments which are production planning and control, personnel management and acquisition of materials must be involved.

2.10. Contributions of TPM towards enhancing manufacturing performance

The manufacturing systems resulting in low productivity and high operating costs due to operate at less than that of full capacity. In the production of goods the cost of operating and maintaining equipment has become a significant factor in an increasing competitive global environment (Kumar Aroor et al., 2015). In order to overcome those problems that manufacturing industries has facing, adoption of strategic changes in management, production, processes, technologies, suppliers and customers is must.

TPM is one method to improve manufacturing performance through an emphasis on maintenance that involves everyone in the organization (Adesta et al., 2018). Total Productive Maintenance (TPM) as the enabling tool to maximize the effectiveness of equipment by setting and maintaining the optimum relationship between people and their machines (Kumar Aroor et al., 2015). It's been known that the maintenance function has gone through many changes over the past few decades. Traditionally the perception of maintenance role was get into action whenever a breakdown occurs. But TPM shifts the paradigm of traditional maintenance systems from being reactive to being more proactive by maintaining equipment's in optimum conditions at all times (Kumar Aroor et al., 2015).

2.11. Key Maintenance performance Indicators (KPI)

Key performance indicator (KPI) is a measurable value that reflects company's critical success factors through quantifiable and strategic measurement. For any companies, without KPIs it is difficult to evaluate performances in a meaningful ways and make a change to address performance related issues. Industries have to find out which area of process needs the most

attention if not they won't know how they are doing. There are number of metrics for maintenance performance indicators. According to (Aziz et.al, 2013)(Baluch N, 2010) the most important KPIs are MTBF (Mean Time between Failures), MTTR (Mean Time to Repair), and Overall Equipment Effectiveness (OEE). Overall equipment effectiveness (OEE) is one of the key performance indicators a manufacturing company can use to determine its performance and total productive maintenance (TPM) has been used to improve OEE in most manufacturing companies.

2.12. Total Productive Maintenance (TPM) tools and techniques

Manufacturing companies have been realized and well accepted tools and techniques of TPM. As the equipment maintenance and reliability are important strategies that significantly influence company's ability organizations to compete effectively, they have to measure and assess their systems using different tools and techniques.

According to (Okpala et al., 2018) some of the tools employed to analyze and solve equipment and process related problems include but not limited to the following: Overall Equipment Effectiveness, Pareto Analysis, One Point Lessons (OPL), 5S Practice, Kaizen (Continuous Improvement), Autonomous Maintenance and Poka Yoke.

Overall equipment effectiveness (OEE)

Overall equipment effectiveness (OEE) is seen to be the fundamental way of measuring performance efficiency (Nallusamy & Majumdar, 2017). It is an effective way of analyzing equipment performance which takes into account the major six big losses which are Downtime Losses, Equipment Failures, Setup and Adjustments, Speed Losses, Idling and Minor Stoppages and Defect Losses (Okpala et al., 2018). According to (Herry et al., 2018) mentioned that in measuring the success of TPM, Overall Equipment Effectiveness (OEE) and Six Big Losses are the methods that are widely used.

As (Kumar Aroor et al., 2015) Overall Equipment Effectiveness (OEE) is the basic measure for Total Productive Maintenance. It highlights the actual "Hidden capacity" in an organization through measuring both efficiency and effectiveness of the equipment. In modern manufacturing industry effectiveness and efficiency plays a major role in determining performance of

production function and level of success achieved in the organization. The losses or gap between 100% and actual efficiency can be categorized in to 3 categories.

Availability

It's a result of breakdowns and changeovers. Occurred when the production line is not working instead it should be. It's the time that a machine is functioning. Equipment should be running for 24 hours per day in a continuous manufacturing organization. Machines availability is determined by equipment break downs, loss of through put (which is caused by equipment malfunction), and set-up and adjustment time which is as a result of equipment change over from one product to another.

Performance rate

Performance rate often called the run rate or machine capability. It occurs as a result of Speed losses and small stops/idling positions, which leads to reduced capacity than standard one. It is measured when the machine is not running according to the design speed of the machine.

Quality/Yield

Also known as yield, it occurs as a result of losses due to defects and start-up- quality losses.

Table2.0.3: OEE and the Six Big Losses

OEE	Six big loss
Availability loss	Equipment failure
	Set up and Adjustment
Performance loss	Idling and Minor stops
	Reduced speed
Quality loss	Process Defects
	Reduced Yield

According to the above table2.3 OEE is a function of the three factors namely Availability, Performance rate and Quality rate.

OEE = Availability X Performance rate X Quality rate.

$$\text{Equipment availability (A)} = \frac{loading\ time - down\ time}{loading\ time} \times 100$$

$$\text{Performance efficiency (p)} = \frac{processed\ amount \times cycle\ time}{operating\ time} \times 100$$

$$\text{Quality Rate (Q)} = \frac{processed\ amount - defect\ amount}{processed\ amount} \times 100$$

OEE is depends on Availability, Performance and Quality rate, it's important to analyze those three parameters to identify hidden problems.

According to (Mentesinot, 2017)(Hanssen, 2002) an overall 85% benchmark OEE is considered as world-class performance. For continuous discrete processes, the OEE should be higher to 90%, whereas continuous stream process industries should have OEE values of 95% or better.

Cause and Effect diagram (fishbone diagram)

Fishbone diagram is a structured way of detailed analysis to find the cause of the problem, variation and gaps. As (Herry et al., 2018) mentioned in their researches the Cause effect diagram contains five main factors that cause problems, which are:

Man: that is related to lack of knowledge, lack of basic skills related to mental and physical, fatigue, stress, ignorance and others,

Method: work method, which is related to no correct, unclear, unknown, non-standardized, unsuitable, and other work procedures and methods,

Machinery or other equipment: there is no preventive maintenance system for production machines, including other facilities and equipment, not in accordance with task specifications, not calibrated and others,

Raw materials: i.e. in the absence of quality specifications of raw materials and materials supporters are used, the absence of effective handling of raw materials and supporting materials and others,

Work environment (work environment): related to place and time of work that does not pay attention to aspects of hygiene, health, safety, lack of lighting, poor ventilation and others.

According to (Okpala et al., 2018)(Strategosin, 2017) TPM tools and techniques description including their purpose summarized in the table below:

Table2.0.4: Tools and Techniques of TPM (Okpala et al., 2018)(Strategosin, 2017)

TMP Tools	Purpose	Description
Autonomous Maintenance	To provide personal care of equipment by the operator.	The operator of the equipment haven understood the functions of the equipment, does activities like Cleaning, lubricating, dusting and inspection. This helps to prevent sudden breakdown of the machine and also give the operators the sense of ownership of the equipment.
Root Cause Analysis	Tackles production problems at the	When root causes are eliminated,

	base level.	breakdowns of equipment are reduced, which would reduce the downtime of machine and ultimately increase the Overall Equipment Effectiveness (OEE).
Kaizen(Continuous Improvement)	Institutionalizes the practice of achieving small daily improvements and improvement of overall efficiency.	Continuous Improvement refers to the idea that a large number of small improvements in processes are easier to implement than major improvements that have a large cumulative effect.
5S Practice	Reduces time wastage and motion level	Organized approach to housekeeping that ensures tools, parts and other objects are in known, optimum locations.
Poka yoke	Prevents the occurrence of mistakes or defects.	Uses a wide variety of ingenious devices to prevent mistakes
One Point Lesson	To provide immediate, visual information that enables people to make correct decisions and manage their work and activities.	One point lesson uses a wide variety of signs, signals and controls, to manage people and processes.

2.13. Summary of Literature Review and Research Gaps

To summarize the literature review parts here are the selected researches in relation with TPM.

(Melesse Workneh Wakjira, 2012) evaluated the contributions of total productive maintenance (TPM) initiatives towards improving manufacturing performance. In their study OEE value calculated and analyzed. The finding from this research was that after implementation of TPM, OEE was showed a progressive growth in which the researchers concluded that OEE improvement was an indication of increase in equipment availability, decrease in rework, rejection and increase in rate of performance. Finally the researchers put a conclusion that managed investment in training and education helps to enhance operator's morals and commitment towards company's goals.

(Lazim et al., 2013) investigated the moderating effect of the level of technical complexity in the production process in the relationship between TPM practices and manufacturing performance. In the study hierarchical regression analysis was used to test the research hypothesis. To validate the hypothesis questioners was used. From the finding in the study that TPM strategy and

planned maintenance found to be related to cost. In which the relationship between TPM strategy and cost is strongest in the case of high technical complexity and weakest in the case of low technical complexity.

(Lemma et al., 2013) used quantitative and qualitative data. The authors developed and proposed maintenance system also developed the implementation of TPM system to preserve the results of model.

(Aziz et al., 2013) in their study identified unplanned machine breakdown time, MTBF, MTTR and Percentage of Breakdown time through Checklist and different charts. The authors used ABC analysis to identify most important departments for a proper planning system for implementing TPM at the initial stage in the organization. In the study they only focuses on the implementation procedure of Focused Improvement (Kobetsu Kaizen) pillar, Autonomous Maintenance (Jishu Hozen) pillar, Planned Maintenance Pillar and Education & Training Pillar. Finally by implementing TPM, the company achieved quick improvement in machine breakdown time, MTBF and MTTR.

(Sivaram et al., 2014) conceptualized the integration of total productive maintenance (TPM) and ISO 9001 certification. The researchers were used experts opinions to analyze their reactions in the relation of "TPM" and "ISO 9001 certification. The finding found from the study, researchers were proposed a model namely TPM 9001:2008 that brings out from synergy the two renowned world class strategies "TPM" and "ISO 9001 certification and the experts agreed that TPM 9001:2008 model would be practically beneficial and compatible to the extent of little more that 80 percent.

(Bartz, Siluk, & Bartz, 2014) presented implementation of a maintenance management model based on total productive maintenance (TPM). The researchers collected and analyzed of industrial performance indicators before the implementation of TPM. After application of the model the collected performance indicators result reveals that the TPM assists in improving industrial performance and competitiveness of the production line studied.

(Mwanza & Mbohwa, 2015) proposed a model for effective implementation of TPM. The methods used in their study were quantitative, qualitative approach and SPSS and Microsoft

excel. Finally the researchers concluded that TPM can be used as a tool to enhance OEE of the company equipment.

(Kumar Aroor et al., 2015) studied TPM and Manufacturing performance of a manufacturing industry by considering two case companies for data collection and TPM analysis work. The researchers used Primary and secondary data's, based on the data collected Overall Equipment Effectiveness (OEE) and Partial productivity determined. Beside correlation analysis which is Karl Pearson's Coefficient of correlation equation was used to find out the relationship between OEE with Availability, Performance and Quality rate, the four TPM pillars also analyzed and finally the result reveals that TPM having direct influence on OEE and as TPM level increases OEE value will also get increase. In the study OEE-Productivity Model developed and proposed. The researchers were concluded TPM is proven to be a program that works. Today with competition in industry at an all-time high TPM may be the only thing that stands between success and total failure for companies.

(Kedar & Borikar, 2016) identified the Critical Success Factors of TQM and TPM. The researchers pointed out which TQM and TPM factors must be considered by managers who desire to successfully implement combined TQM and TPM approach within their firms.

(Nallusamy & Majumdar, 2017) carried out a study to improve the utilization of machine tool and manpower by initiating the practices through TPM. Pareto chart and cause and effect diagram tool was used to measure performance also a TPM tool was used to measure performance before and after TPM implementation. Finally the researchers found a result in reduction in setup time, cycle time, breakdown losses and rework time, and overall equipment effectiveness increased by about 15%.

(Venkateswaran, 2017) examine the advanced methodologies that can be implemented to bring improvement of the process. In the study the method used are Pareto chart, Histogram, Why-Why analysis, Fish bone diagram, Pie chart. To analyze maintenance performance of machine, overall equipment effectiveness (OEE) was computed. The finding of the research was OEE (Overall Equipment Effectiveness) has increased and In-process scrap gets reduced.

(Kumar et al., 2017) established a breakdown analysis to identify section wise, type wise and the particular equipment in which maximum breakdown occurred. Three machines were selected in

which maximum breakdowns occurred and recommended Corrective Action & Preventive action for those particular machines.

(Díaz-Reza et al., 2018) proposed a structural equation model that relates three CSFs managerial commitment, TPM implementation, and PM implementation, which are related to productivity benefits. In the research questioners used to validate the research hypothesis. The results showed that managerial commitment is critical to achieve productivity benefits, while preventive maintenance is essential to total preventive maintenance.

(Herry et al., 2018) analyzed TPM implementation level through determining of OEE value and comparison with OEE world class and other industry, Pareto diagram analysis for six big losses, fishbone diagram analysis to determine biggest losses and main cause. Based on the result of OEE and losses, the company implemented the concept of TPM quite well at the Medium level of implementation.

(Martomo & Laksono, 2018) measured the achievement of overall equipment effectiveness (OEE) value and identified the six big losses that occurred. The finding from the research reveals that low OEE and the researchers proposed improvement action through application of autonomous maintenance, providing training for operators and maintenance technicians and supervising operators in the workplace.

(Oleghe & Salonitis, 2019) investigated concepts relating to TPM practices through a system dynamics-discrete event simulation (SD-DES) hybrid modeling framework, SD modeling was used to model intangible aspects which are worker motivation, attitude and compliance level to do optimal maintenance. The result from simulation reveals that intangible human factors such as worker motivation do not significantly affect TPM performance.

(Abhishek Jain, 2018) identified the key enabler for Total Productive Maintenance (TPM) implementation. The researchers were used questionnaire survey, expert opinion and Graph Theoretic Approach (GTA) to evaluate the feasibility/suitability of TPM implementation. From the finding of the study the key enablers identified were Motivation, Total employee involvement, Employee empowerment, Team spirit, Positive attitude, various maintenance systems, Education and training, Available resources.

Research Gap

Literature reviews has been conducted considering TPM related and others. It's seen that TPM importance in improving performance of manufacturing industries. According to (Patil et al., 2018b) TPM is a well-known strategy for improving the performance of maintenance activities. From the review a lot of research work had done:

- Regarding TPM implementation
- Barriers in implementing TPM
- Effect of TPM implementation on OEE
- Advantages/benefits achieved after implementation of TPM
- Practicing some TPM pillars and determining OEE before and after implementation.

As (Hj. Bakri et al., 2014)(mckone et al., 1999) argued that one of the major reason to the pitfalls of TPM implementation in many companies were due to failure in identifying the actual construct that most affected the TPM implementation. This means every industry have their own work cultures, management style, employment skill level/perception, attitude and others, therefore the existing company status has to be studied before goes to the implementation processes. As (Díaz-Reza et al., 2018) mentioned that many studies have reported the key activities involved in TPM factors besides the benefits obtained. However, the relationship between the success factors and company benefits has not been clearly defined. CSFs of any industries vary from one to another and the finding also cannot be generalized. To do so it is necessary to understand various critical success factors and their impact related to the manufacturing performance.

Accordingly the researcher focuses more on evaluating critical success factors that affect maintenance performance of the company and study significant contribution of those factors towards maintenance performance of the company.

2.14. TPM critical success factors and maintenance performance

Different studies investigate TPM CSFs where the issues discussed are varied. In order to achieve successes, organization needs to consider elements of CSFs in TPM program. The researcher have been conducted a literature review from different researches that has done regarding TPM and other maintenance related. The literatures that have reviewed in this research mostly focused on the benefits gained after implementation of TPM and this was verified

through determining OEE only. TPM is more of a mindset continuous processes and it took some time to get result after implementation therefore, it need to clearly investigate what exactly the existing system of the company that is going to adopt this tool. To do this it needs to develop TPM framework considering the company existing situations by giving priority for the most important areas that has to be improved. TPM critical factors of any industries vary from one to another and the finding also cannot be generalized. This means one factor that is the most important for a company might not be important for another company. Accordingly TPM critical factors should be selected based on the company situation.

As (Rajdeep Singh, 2017) mentioned TPM brings the maintenance in the business and focuses on the central and vital parts of the necessary business. Bringing maintenance in the businesses and making it more effective and efficient is the key tasks in TPM program. For this matter improving maintenance performance is the most important thing that should be given a priority in the process. Accordingly maintenance performance could be affected by different factors i.e. it could be human factor, system factor, skill factor, management factor or any other means. Each factors contribution in the performance of maintenance cannot be known unless studied its significant level therefore, the researcher's focuses in investigating TPM success factors impact on maintenance performance.

2.14.1. Maintenance Performance and Measurement

Now a day's manufacturing systems have become continuously complex with the introduction of new technologies and are more costly to operate and maintain (Kumar Aroor et al., 2015). Due to this reason, Maintenance is one of the areas to be given due consideration in modern management to increase machine productivity and to produce quality products as well (Lemma et al., 2013). In this fast and challenging business environment the competitions among organizations gets higher and industries have to importantly consider reliable equipment's. As (Bartz et al., 2014) stated that for a production system to act without waste and be profitable, the maintenance system should operate effectively. This becomes necessary because the large investments made in organizations should generate profits and the best way to maintain the operation of equipment is by managing its maintenance beside there has to be effective integration of maintenance function with engineering and other manufacturing functions in the organization. To support production, maintenance must guarantee equipment availability in order to produce products at the required quantity and quality levels to do so an engineering

assets of maintenance performance needs to be assessed and measured in order to be managed effectively and efficiently.

As (Venkateswaran, 2017) mentioned that most of the production and their total production cost (30-50%) are currently undertaken within the factory, due to this business profitability greatly affected because of quality of maintenance. It is important for the firm to improve the maintenance cost since it's entirely affected the operating budget of many manufacturing firms.

The measurement of maintenance performance has essentially become an essential element of strategic thinking for service and manufacturing industry since the basic purpose of any measurement system is to provide feedback, relative to company's goals, that increases chances of achieving these goals efficiently and effectively. The purpose of measuring performance is not only to find out how the company is performing but it also helps to perform better. Maintenance performance can be improved by making it more effective and more efficient. Effective maintenance is doing the right maintenance: that which brings higher equipment reliability and lower operational risks. Efficient maintenance is doing maintenance right so that reliability and risk reduction are achieved with the least resources and time. Accidental breakdowns and downtime of plant and machineries have high impact on the plant capacity, product quality, and cost of production, as well as health, safety and the environment.

According to (Shahin, 2014) Performance Indicators are needed in order to be able to control maintenance processes while various researches have been done attempting to develop maintenance performance measurement and Overall Equipment Effectiveness (OEE) is the most suggested for measuring maintenance performance in the existing resources. However, it does not provide the means for a complete performance analysis in maintenance. A maintenance function consists of human and system elements (Oleghe & Salonitis, 2019) (Shanmugam, A. and Paul Robert, 2015). Many problems in production are multifaceted and involve human-related actions/inactions (Oleghe & Salonitis, 2019).

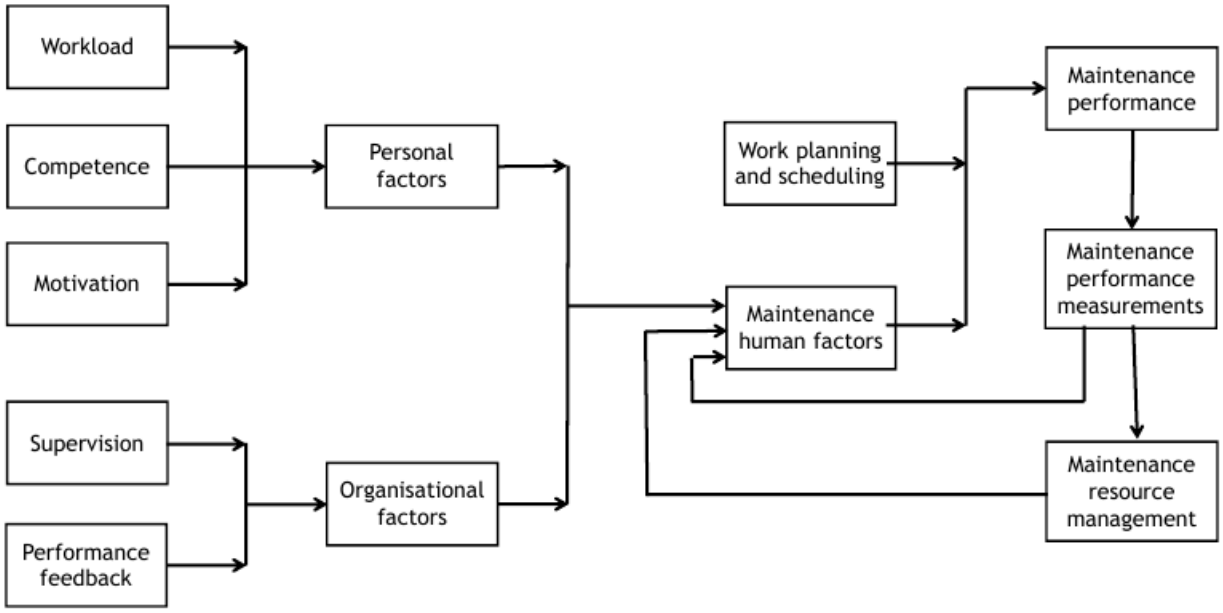


Figure2.5: Relationship between maintenance human factors, maintenance performance measurements, and maintenance performance (R. Peach, 2016)

In the above figure a maintenance performance measurement framework proposed by (R. Peach, 2016). The proposed framework considered the three factors which are maintenance human factors, maintenance performance measurement and maintenance performance. The researcher concluded that personal factors which are competence (skill levels) and motivation are the most important maintenance human factors that influence the maintenance performance.

2.14.2. Selected Key maintenance performance indicators

The researchers has been evaluated performance indicators from different researchers and considering the company current conditions and observed problems the selected indicators for maintenance performance are the following for further study:

- **Availability (A):** Occurred when the production line is not working instead it should be.
- **Mean time between failures (MTBF):** measure of the predicted time between one break down to the next during normal operation.
- **Mean time to repair (MTTR):** repair time, testing period, and return to the normal operating condition
- **Overall equipment efficiency (OEE):** measure productivity of equipment

2.14.3. Total Productive Maintenance (TPM) Critical Success Factors

Critical Success Factors (CSFs) are relevant performance areas that help companies reach desired goals. The important benefits of TPM success factors help to provide opportunities to develop suitable strategic plans for company's capabilities and human resources to support integration between the operation and maintenance departments, and improve business relationships with customers and suppliers. As (Díaz-Reza et al., 2018) mentioned that many studies have reported the key activities involved in TPM factors besides the benefits obtained. However, the relationship between these success factors and company benefits has not been clearly defined. CSFs of any industries vary from one to another and the finding also cannot be generalized.

As (Melesse Workneh Wakjira, 2012) mentioned in their study that the significant contributions of TPM implementation success factors are top management leadership and involvement, traditional maintenance practices and holistic TPM implementation initiatives towards affecting improvements in manufacturing performance. In the study by (Gupta et al., 2015) identified the following major contributing critical success factors for the successful implementation of TPM in the organizations which are Strong commitment by Top Management, Total employee involvement, Effective implementation of TPM initiatives, their monitoring and follow-up, Compatibility between business plans of the company with the TPM goals, appropriate transformation in organizational culture and Adequate training for the skill enhancement of the worker. As (Díaz-Reza et al., 2018) said that true power of TPM is using employee knowledge and experience to generate ideas to achieve the desired goals and objectives. (Abhishek Jain, 2018) selected motivation, total employee involvement, employee empowerment, team spirit, positive attitude, various maintenance systems, education and training, available resources, etc. are also the key enablers therefore, it becomes necessary to understand the nature of various enablers and their impact.

(Díaz-Reza et al., 2018) (Piechnicki et al., 2015) identified a set of critical TPM success factors and grouped them into eight categories: education and training, teamwork, planning and preparation, senior managerial commitment, resistance to change, change of culture, employee involvement, monitoring results, and effective communication. In their study (Rajdeep Singh, 2017)(Ng, K. C et al., 2013) identified the critical success factors of Total Production

Maintenance tool implementation, these success factors include top level commitment, cultural change, training and development, clear vision and mission, language problems, and effective communication.

As (Kedar & Borikar, 2016) in their study identified implementation factors of TQM and TPM which have positive impact on the organizational performance which are leadership, customer satisfaction, continuous improvement, process management, strategic planning, training and education, housekeeping, team work, supplier quality management, equipment management, result and recognition, people management and total employee involvement.

From the study by (Hj. Bakri et al., 2014) mentioned only three common CSFs constructs covered by most of the frameworks namely management commitment and leadership, total involvement of employees, training and educations. As (S. N. Seleem, 2018) indicated that Cross-functional team work, setting organization objectives, providing on-job training and Availability of information are the most critical success factors for TPM program.

Different researchers put CSFs in their studies, as it was mentioned in the above CSFs are different from industry to industry. In the present study, TPM critical success factors have been identified for analyzing the impact of TPM CSFs towards realizing maintenance performance.

2.14.4. Selected TPM Critical Success Factors (CSF's)

According to (Díaz-Reza et al., 2018) identifying CSFs allows company managers and administrators to prioritize the activities that ensure TPM success. The researchers have been reviewed different critical success factors identified in many researches and considering the factors that have found, the case company current situations studied through informal interview with top management members, maintenance directors of regular and security printing, maintenance team leader and engineering experts beside observation also conducted. Accordingly, the identified TPM critical success factors are involvement of employee's and top management, employee motivation, the maintenance strategy used, level of skill & experience, availability of maintenance manuals, effectiveness of equipment and the status/ condition of technology, availability of spare part, training and education, relationship with suppliers and tools and equipment's for maintenance are the factors that are found from the company through interview and observation.

After identifying TPM CSF's specific to the case company, the researchers consider the following procedures to select those identified factors for further study:

- Selected the CSF's found from the company that has similarity with the CSF's identified from different researchers. This is due to the reason that the selected CSFs have to be based on the company construct.
- To easily understand and recognize which critical success factor belongs to who/whom, the CSF's that are selected grouped in a category.
- CSF's that has to be considered by the company/organization categorized under organizational factors.
- CSF's that has to be considered by the employees categorized under human factors
- CSF's that has relation with the technology categorized under technological factors.
- CSF's that has relation with resource categorized under resource factors.

Accordingly, the CSF's selected has to be studied further that to find out whether their impact have strong in affecting the maintenance performance of the company.

As per the above procedures the followings are the selected CSFs and its sub factors for further investigation in this research:

1. Organizational factors
    - Top Management involvement's
    - Training and education
    - Maintenance strategy used
    - Supplier relation
    - Spare part availability
2. Human factors
    - Level of skill & experience
    - Employees involvement
    - Employee Motivation
3. Technological factors
    - Technological status
    - Equipment effectiveness
4. Resource factors
    - Technical manuals

- Test equipment's and tools

2.14.5. Conceptual Research Framework

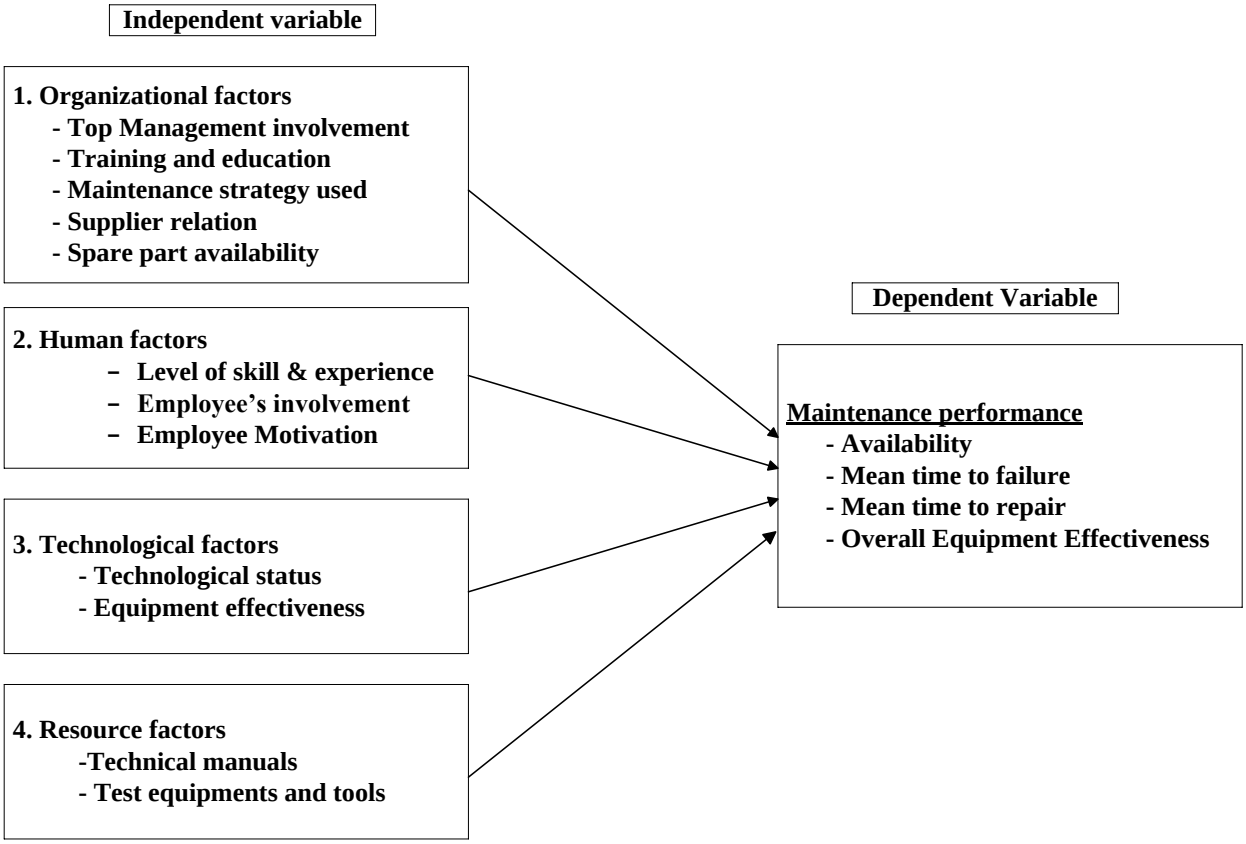


Figure2.6: Conceptual research Framework (source: own)

2.14.6. Hypothesis Formulation

To study the significant impact of the critical success factors of TPM towards maintenance performance, the researcher selected TPM CSFs considering identified CSFs from different researches specific for the case company. As per the identified CSFs, hypothesis formulated for testing based on the relationship of the conceptual framework in the above figure2.6.

The hypotheses that the researcher formulated for testing are:

H1: An organizational factor has a positive impact on maintenance performance of the company.

H2: A human factor has a positive impact on maintenance performance of the company.

H3: A technological factor has a positive impact on maintenance performance of the company.

H4: A Resource factor has a positive impact on maintenance performance of the company.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

Methodology refers to a systematic way to conduct a research that containing various techniques of data collection, methods and tools of analyzing the data. This chapter discusses an overview of the approaches adopted for the study.

3.2. Data Collection

Data collection is a process of gathering information's that are relevant to accomplish the research or the study. There are two data collection methods such as primary and secondary data collection and the researchers used both of the methods. The sources of data utilized in the study namely primary and secondary data sources. Under this two methods literature review, interview, questionnaires and observation has been used.

Primary data collection is one of the methods used in this research. Under primary data collection the three mostly used methods which are observation, interview and questionnaires have been used.

a) Observation

Observation is one way of primary data sources. It's a method of watching and listening to an interaction or phenomenon where it takes place. In order to understand the facts about the case company actual production process i.e. how exactly the existing system is working, maintenance activities used, the situations that the company doing things, how technicians perform their maintenance routines and others things related to maintenance activities have been observed.

Concerning the critical successes factors, different researchers putted many factors in their study. Depending on the critical factors that different researchers identified, observation conducted in the case company and critical successes factors for the research has been identified.

b) Interview

Interview is one of the tools used to gather data. Due to its useful in achieving high response rate and in obtaining detailed information about perceptions, feelings and opinions of the person that is going to be interviewed, this method have been used in the study.

The researcher has conducted an informal interview beside observation that to select the critical successes factors for the company which are going to be studied further. As per the identified

CSF that different researchers putted in their study, informal interview has been conducted with Regular printing maintenance director, maintenance team leader, Engineering experts and some high level maintenance technicians.

c) Questioners

Questioners are the main tools in collecting data. The researcher developed questions considering the success factors of TPM that are selected for this study and other related issues included. The questionnaires developed and categorized based on the level of the positions i.e. for some top management members, maintenance team leader, engineering experts, maintenance technicians, and operators. In developing questionnaires the researcher reviewed several researches. The questionnaires prepared for some top management, maintenance department and production department considering the direct relation with respect to the work positions that are engaged with. As much as possible the questionnaire was prepared to make it easy for the participant which is closed ended. In order to gather relevant information to conduct the study the questionnaires was distributed and collected by the researcher. The questioners distributed under each area for top management members, departments head, engineers, maintenance technicians and operators, with a total number of 138.

In addition primary data secondary data has been collected from the case company reports, documents and also from the literature regarding the research areas

a) Literature Review (Previous Research)

As secondary data to gain understanding about the role of various maintenance concepts, maintenance trends presented by different researchers and create strong foundation, the research work begun with an extensive literature study. Considering the research title the literature review method categorized into three areas which are TPM related, maintenance related and maintenance and performance related researches this is due to the reason that to find out how far researchers had done in those areas.

b) Case company Documents

The researchers have gone through collecting the company record data. To analysis the existing company situation and investigate in detail, company recorded data is necessary. Accordingly, company reports, production machineries planned and accidental maintenance data, downtimes

registered due to machines failure and other related company data have been considered in the study.

3.3. Sampling (Sampling Plan) and sample size

The critical part of the research is the way that we have selected a sample of individuals. Accordingly this section consist a clear description about the target Population that is clearly defined, the sampling technique chooses, and sample size determined.

Target population

Target Population refers to a total group of individuals or objects that researchers are interested. Accordingly in this research the target populations are some selected top management members, maintenance leader, maintenance technicians, Engineering experts and production operators.

Sampling Techniques

Purposive sampling

This type of sampling techniques are used when the researcher consider limited number of peoples who has skill and knowledge in the area. Accordingly the researcher has used purposive sampling due to the reason that the research area includes those who have skill.

During sampling two considerations have been taken,

1. All the maintenance technicians and engineering expert from maintenance department have been taken for participation of data collection because each staffs of maintenance departments are directly engaged with the maintenance activities in a daily basis this means a significant data can be found from those peoples who has a direct relation.

Since the number of staff in maintenance department including maintenance leader is 43, accordingly all the member participated in the data collection.

From the top management the members that has selected for the data collection are regular printing maintenance directorate director, Security printing maintenance directorate director, Supply and Logistics Directorate director, Information analysis team leader and Asset management and control team leader. Due to the reason that has close relation with maintenance, supply and equipment management related. Accordingly, from the top management members the number of participants for data collection is 5.

2. The number of population under production departments are so many and it's not possible to take all the population for the study in addition the research area has a direct relation with the

people who has engagement with maintenance activities in a daily basis accordingly, for the production operators to decide the participants for the data collection sample size determined

Sample size

To get a representative and reasonable sample size that supports the research findings, the following equations are used.

According to (Othman, 2014) (Johnson et.al, 2009) (Freedman et al., 2007) the following equations can be applied to compute the sample size:

$$no = \frac{z2 \times p(1-p)}{c2} \quad \ldots\ldots 1 \qquad nf = \frac{no}{1+\frac{no-1}{N}} \quad \ldots\ldots\ldots 2$$

Where:

n_0 = initial sample size n_f= target sample size

Z = Z-values for confidence levels are (1.645 for 90% confidence level, 1.96 for 95% confidence level and 2.576 for 99% confidence level)

p = percentage picking a choice, expressed as decimal 0.5 used for sample size needed

c = confidence interval, expressed as decimal; 0.08 = ±8

N = Population = 222 workers (regular and security printing section supervisor and operators)

$$no = \frac{(1.96)2 \times 0.5(1-0.5)}{(0.08)2} = 150.06 \qquad nf = \frac{(150.06)}{1+\frac{(150.06)-1}{222}} = 89.77 \sim 90$$

Therefore, the number of participant of operators in the data collection is 90

Note: The total number of participants for the data collection is 138.

3.4. Data Analysis Tools

To get the desired outcome from the study the collected data has to be analyzed. Different tools and methods have been used in different researches in analyzing data; it might be software or any other means. Tools and method has to be selected as necessary that to get a meaningful result. Accordingly the researcher selected different tools in this study to analyze the data collected from questionnaires and company registered data.

Overall equipment effectiveness (OEE)

It's a quantitative metric that has been increasingly used in manufactory systems for controlling and monitoring the productivity of production equipment, and also as an indicator and driver of process and performance improvements (Mentesinot, 2017) (Tsarouhas, 2013). OEE is considered as one of an indicator of maintenance performance through measuring all losses,

under three category availability, performance and quality. Accordingly due to OEE plays an important role in measuring equipment availability, performance rate and quality rated and addresses all losses caused by equipment faults, the OEE calculation used in this study.

Cause and Effect Analysis (Root cause Analysis)

It's a much known tool that helps to identify, sort, and display possible causes of a specific problem. A cause-and-effect diagram is a tool that is helpful for identifying and organizing the causes of a problem such as equipment failure and assessing the reasons for repetitive machine failure considering different factors. The structure of the diagram provides a very systematic way of thinking about the causes of a particular problem. Due to its advantages in identifying the root cause for specific problems, cause and effect analysis used in this research. .

Statistical Package for the Social Sciences (SPSS)

SPSS is the most popular used software, its application and role is limitless. This software used to analyze the collected data from questionnaires. To determine the strength of relationships between the variables which are Organizational, human, technological, resource factors and maintenance performance, Pearson correlation coefficient (r) used. Besides determining the strength between the independent variables and dependent variables, regression analysis has been used the tests included ANOVA F-test, Beta coefficient and other test.

3.5. Validity and Reliability Test

Validation

The researcher has done validation of the draft questionnaires to guarantee it clarity and validity. In this regards the draft questionnaires, it was given to the advisor and co advisor for review and feedback. As per the comment validation was conducted and the researcher has done some changes to keep its flow.

Reliability Test

To produces stable and consistent results of the study, the researcher has done reliability test. Accordingly the most common technique used to evaluate the scale's reliability and stability is Chronbach Alpha Statistics. It's the most common technique used in the literature to evaluate reliability and stability. According to (H/Mariam, 2018) (Syum, 2010) reliability coefficient of Cronbach's alpha of 0.70 or higher is considered acceptable. Where Cronbach's alpha of 0.7 and above is good, 0.8 and above is better and 0.9 and above is best. Accordingly the researcher

conducted reliability test and the finding reveals that the Cronbach's alpha of 0.949 which is best.

Case Processing Summary

		N	%
Cases	Valid	121	100.0
	Excluded[a]	0	.0
	Total	121	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.949	29

The researcher conducted reliability test for each factors and as per the result finding from the SPSS output presented below

Table3.1: Chronbach apha for each factor

Reliability Statistics

Factors	Cronbach's Alpha	N of Items
Organizational factors	0.762	10
Human factors	0.881	7
Technological factors	0.954	2
Resource factors	0.719	4
Maintenance performance	0.970	6

0.70 Cronbach's Alpha value is a "commonly used threshold for acceptable reliability", and according to the table3.1 above all Cronbach alpha scores for each factor were in the acceptable range from 0.719 to 0.954.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1. Introduction

This chapter includes the data analysis and discussion or interpretation of the result found from the analysis. The researcher has been used primary and secondary source of data's to conduct the study. Accordingly here are the data analysis, presentation and discussion:

4.2. Data collection (survey questionnaires) and Analysis

The questionnaire was distributed after making a lot of improvements to assure its clarity. After correction the questionnaires were distributed to the top management members, maintenance team leaders, engineering experts, maintenance technicians and production operators. The questionnaires has three sections, the first section were about the general information of the participants regarding the educational background, experience in the company and their working position. The second section contains in relation with the critical success factors and maintenance performance of the company. The final third section was about maintenance activities related.

As per the distributed questionnaires for 138 participants, the collected questionnaires were about 121 respondents. Accordingly the survey questionnaires data analysis, presentation and discussion of the results are presented as follows:

4.2.1. Demographic Data presentation and Discussion

General information

The survey questionnaires were started from the general information in relation with the personal status of the respondents. Accordingly to describe the characteristics of the respondents such as work experience, work position and educational background, the analysis starting from the general information of the respondents.

In the table4.1 below general information of the respondents summarized as follow:

Table 4.1: summary of respondent's general information

Variable		Number of respondent	Total respondents (Base on related dep't)	% of respondents
Work position	Top management members	5	5	4.1
	Maintenance team leader	2	4	3.3
	Engineering expert	2		
	Maintenance technician (mechanical)	17	33	27.3
	Maintenance technician (electrical)	13		
	Maintenance technician (workshop)	3		
	Supervisor	7	7	5.8
	Higher printing operator	23	36	29.7
	Higher post printing operator	13		
	Middle printing operator	12	22	18.2
	Middle post printing operator	10		
	Lower printing operator	7	14	11.6
	Lower post printing operator	7		
	Total	**121**	**121**	**100**
Total work experience in the company	<5	30	30	24.8
	5 – 10	40	40	33
	>10	51	51	42.1
	Total	**121**	**121**	**99.9**
Education level	10+1	0	0	0
	10+2	47	47	38.8
	10+3	31	31	25.6
	10+4	0	0	0
	Degree	39	39	32.2
	Master	4	4	3.3
	Total	**121**	**121**	**99.9**

In the table4.1 above it shows that respondents based on working position, total work experience and educational level. Accordingly, the number of respondents based on the working position that they are engaged, 29.7 % of the respondents are higher level printing and post printing operators, 27.3% covers respondents that are maintenance technicians, 18.2% covers middle level printing and post printing operators, 11.6 % of respondents are lower level printing and post printing operators and the others are top management members, maintenance team leaders, engineering experts and supervisors with respondent percentage of 4.1%, 3.3% and 5.8% respectively. From this the highest respondent coverage is 29.7% and 27.3% which are the higher printing operators and maintenance technicians accordingly, this implies that the chance of getting relevant response is higher due to the relation of TPM concepts regarding to those maintenance persons and machine operators is very strong.

In regarding to the respondents working experience in the company, 42.1% of respondents indicated that they have greater than 10 years of working experience, 33% of respondents have between 5 to 10 years of working experience and the others 24.8% of the respondents indicated that they have less than 5 years of experience in the company. From this the highest percentage of respondent is 42.1% which have working experience above 10 years accordingly, this indicates that getting the relevant data from those respondents that have more than 10 years working experience is very high this is because the probability of having a well detailed information of the company is high due to their years of stays in the company.

According to the respondents concerned to educational background, 38.8% of the respondents have 10+2, 32.2% of the respondents have Degree, 25.6% of the respondents have 10+3 and the rest 3.3% have masters. From all the highest respondents are covered by educational background of 10+2 and degree which is 38.8% and 32.2% respectively. This indicates there is a high chance of getting fair and relevant responses from the respondents.

4.3. Machine Downtime Analysis and Discussion

The researcher has done downtime analysis for the machines which are found in the four sections of the company such as offset printing section, wave offset printing section, letterpress section and security printing sections.

a) Offset printing section

The total downtime registered for each machines in offset printing section

Table 4.2: planned production time and total downtime of machines in offset printing section

(Source: company data)

Machine Name	planned production time	Total Downtime	Net operating time	Productive time (%)	Non-productive time (%)
M-Offset	3090	1693.26	1396.74	45.2	54.8
Speed Master102/1	1551.5	1203.03	348.47	22.5	77.5
GTO-15	3090	815.47	2274.53	73.6	26.4
Speed Master74/2	3090	1245.35	1844.65	59.7	40.3
Sakurai-Awarie	3090	2318.54	771.46	24.9	75
Sakurai 266-1	3090	1561.56	1528.44	49.4	50.5
GTO-46	3090	803.29	2286.71	74	26
New M-Offset-031	3090	1340.1	1749.9	56.6	43.3
GTO-New	3090	897.92	2192.08	70.9	29

In the table4.2 above the planned production time and downtime of machines in the offset printing section that was registered in the year 2010 E.C (2017/2018).

Accordingly in the figure4.1 below the chart clearly seen that the percentage of the productive and non-productive time in the offset printing sections.

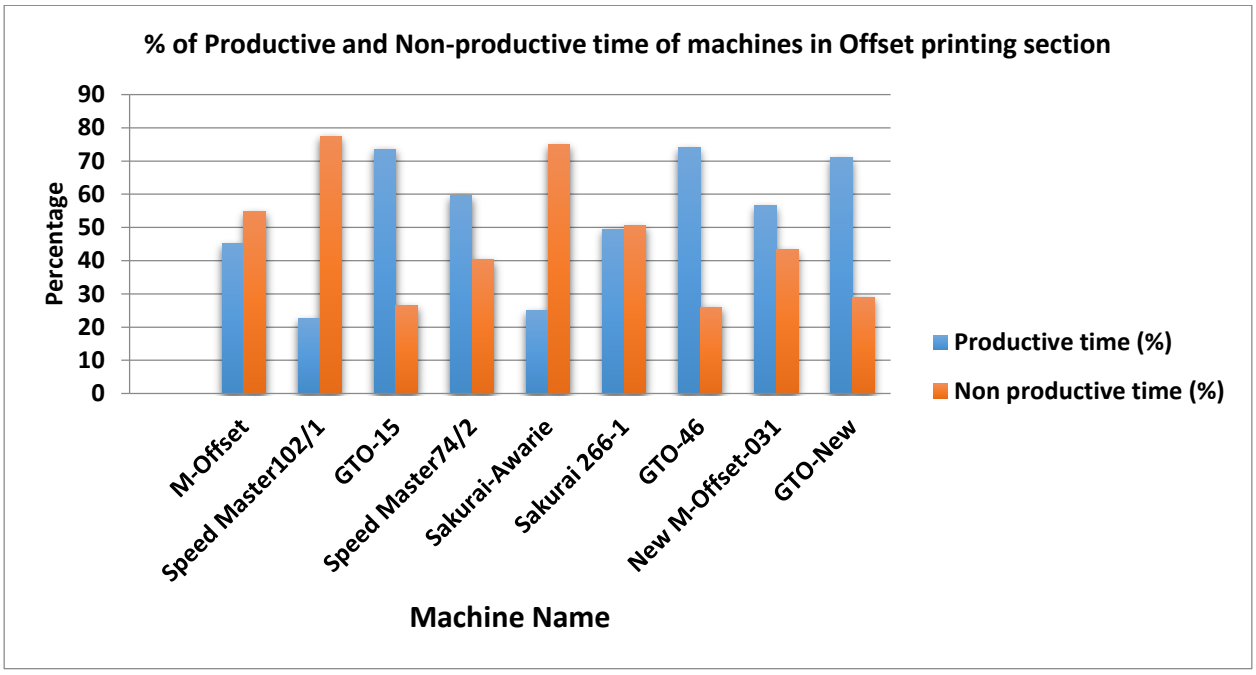


Figure4.1: Productive and Non-productive percentage of machines in offset printing section

In the figure5.1 above productive and non-productive percentages of each machines that are found in the offset printing section clearly seen in chart. The highest productive and non-productive value is 73.6% & 77.5% respectively. The lowest productive and non-productive value is 22.5% & 26 % respectively. The result reveals that due to accidental machines failures there is high occurrence of downtime in the section that disturb the planned production time this prolonged downtime occurred due to machine failures clearly indicated that the company maintenance performance is very poor. If there was effective maintenance performance there shouldn't be this amount of downtime registered in the first place.

b) Wave offset printing section

The total downtime registered for each machines in wave offset printing section

Table 4.3: planned production time and total downtime of machines in wave offset printing section

(Source: company data)

Machine Name	planned production time	Total Downtime	Net operating time (%)	Productive time (%)	Non-productive time (%)
Solna 1	3090	2462.55	627.45	20.3	79.7
Solna 2	3090	2687.10	402.90	13	86.9
Wive546	3090	2654.92	435.08	14	85.9
Wive578	3090	2460.34	629.66	20.4	79.6

In the table4.3 above the planned production time and total downtime that was registered in wave offset printing section for the year 2017/2018 presented

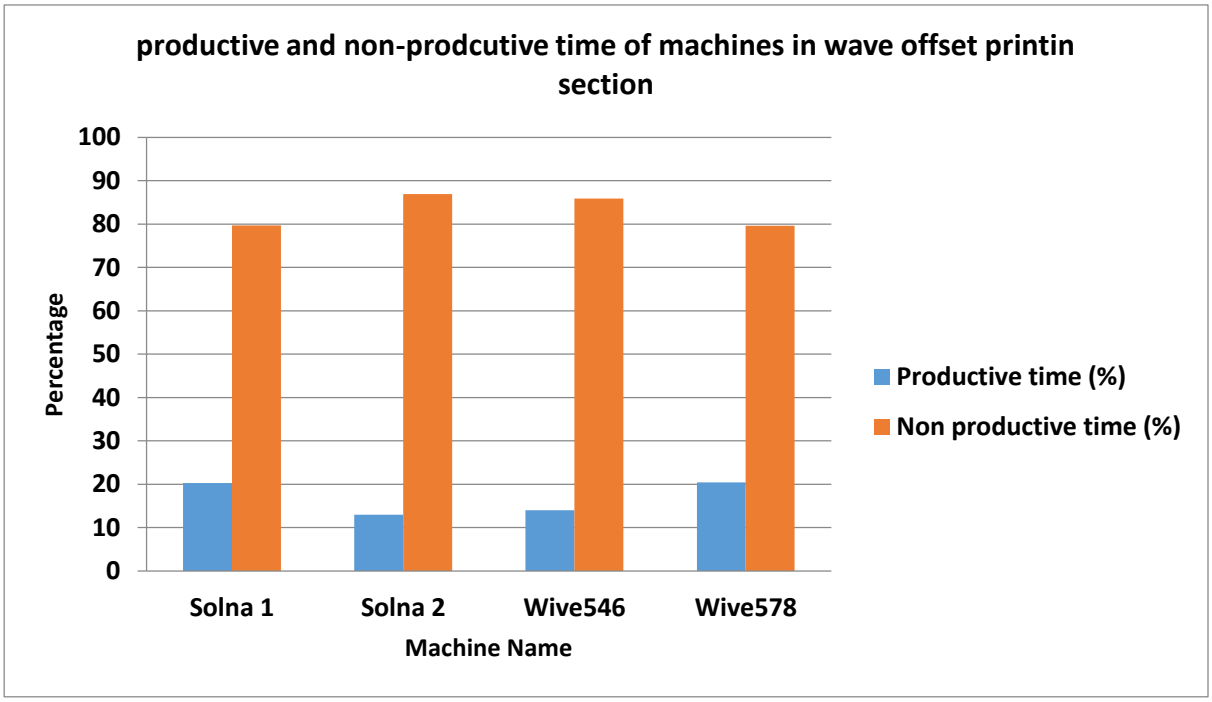


Figure 4.2: Productive and Non-productive percentage of machines in wave offset printing section

In the figure4.2 above the chart clearly explain the productive and nonproductive time of machines in the wave offset printing section. From the chart the maximum and the minimum value of productive time is 13% and 20% respectively whereas the maximum and minimum value of the non-productive time is 79% and 86 % respectively. From the result obtained the maximum values belongs to the non-productive time. According to the result obtained as non-productive time, it's a clear indicator that the company maintenance performance is very low.

c) Letter press printing section

The total downtime registered for each machines in wave offset printing section

Table 4.4: planned production time and total downtime of machines in letterpress printing section

(Source: company data 2017/2018)

Machine Name	planned production time	Total Downtime	Net operating time	Productive time (%)	Non-productive time (%)
GTO2-026	3090	1460.31	1629.69	52.7	47.2
GTO1-027	3090	3090	0.00	0	100
GTO3-028	3090	3090	0.00	0	100
platin-22	3090	418.66	2671.34	86.4	13.5
Cylinder-09	3090	576.88	2513.12	81.3	18.6
platin-024	3090	393.21	2696.79	87.3	12.7
Cylinder-30	3090	615.87	2474.13	80	19.9

The table 4.4 above shows the company registered production time and downtime in the letter press section for the year 2010 E.C. (2017/2018).

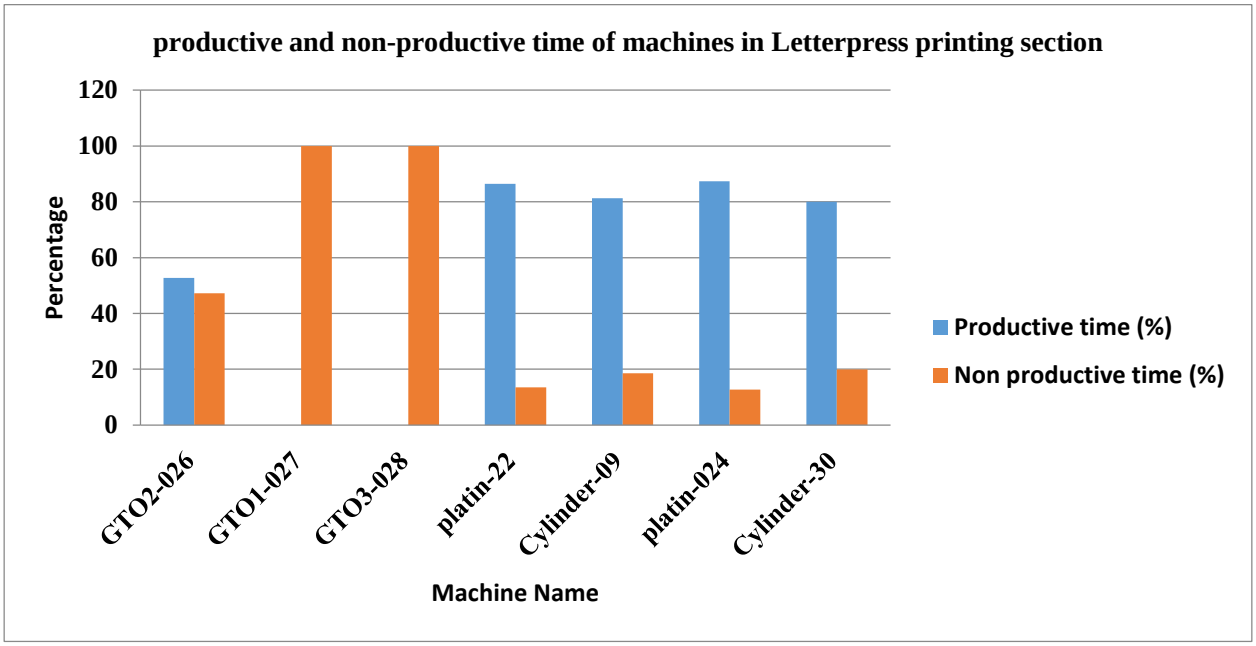


Figure 4.3: Productive and Non-productive percentage of machines in letterpress printing section

In the figure4.3 above the chart reveals that percentage of productive and non-productive time in the letter press section, accordingly in the section the two machines called GTO-027 and GTO3-028 was 100% non-productive during the year. The implication from the result is that the company maintenance performance is very poor due to that there are frequent machine failures and high amount of downtime.

d) Security printing section

The total downtime registered for each machines in wave offset printing section

Table 4.5: planned production time and total downtime of machines in security printing section

(Source: company data)

Machine Name	planned production time	Total Downtime	Net operating time	Productive time (%)	Non-productive time (%)
platin-02	3090	977.86	2112.14	68.3	31.6
Cylinder-08	3090	714.61	2375.39	76.8	23.1
platin-013	3090	432.38	2657.62	86	14
platin-014	3090	848.29	2241.71	72.5	27.4
Cylinder-15	3090	854.83	2235.17	72.3	27.6
Cylinder-16	3090	641.39	2448.61	79.2	20.7
platin-021	3090	373.90	2716.10	87.9	12.1
platin-026	3090	430.35	2659.65	86	13.9
Speed Master102/1	2359.00	1104.29	1254.71	53.1	46.8
Roland-200	1509.00	161.74	1347.26	89.3	10.7
Sakuri 266/2	2785.00	674.19	2110.81	75.8	24.2
Cylinder-28	3090.00	345.75	2744.25	88.8	11.1
Roland-10	1396.00	1396.00	0.00	0	100
Sakuray1	1514.25	1291.77	222.48	14.7	85.3
Sakuray2	3090.00	1088.14	2001.86	64.7	35.2

The table4.5 above shows the company registered production time and downtime for the machines in the security printing section for the year 2010 E.C. (2017/2018).

Accordingly the bar chart below clearly shows the productive and non-productive time of each machine in the section.

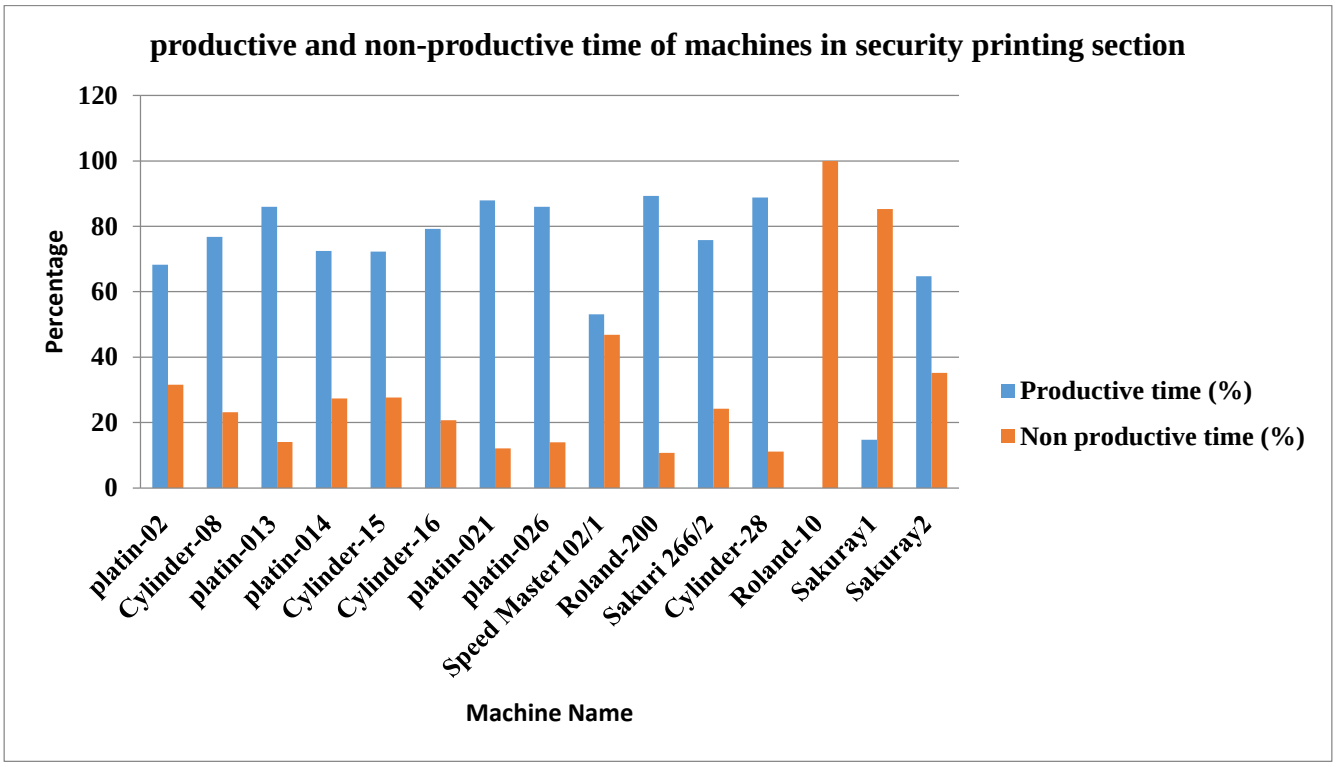


Figure 4.4: Productive and Non-productive percentage of machines in security printing section

As per the figure4.4 above the productive and non-productive time of each machine clearly stated, in this section one of the machines called Roland-10 was 100% non-productive during the year. Machine called Sakuray1 was 85% non-productive and the others machines in the security printing section have also non-productive time between 10–47 % during the year. From the result obtained the analysis of productive and non-productive percentage for the machines in security printing section reveals that in the section there was high occurrence of downtime that influence the planned production time.

4.4. Machine performance Analysis and Discussion

4.4.1. Overall equipment Effectiveness (OEE) calculation

To study the existing situation of the company regarding to the maintenance and machine performance, secondary data collected and analyzed using of OEE.

Machine Performance is expressed in terms of overall equipment effectiveness (OEE). As per the collected data from the case company, OEE determined for the machines that are found in each printing sections of the company such as offset printing section, wave offset printing section, letter press printing section and security printing section.

Accordingly, to compute OEE the formula expressed in three terms which are availability, performance and quality:

$$OEE = Availability \times Performance \times Quality$$

Note: To calculate OEE for each machine the data that has taken for 12 months' from Hamle 2009 E.C up to Sene, 2010 E.C (2017/2018).

a) Offset printing section

In this section different machines are used for printing purposes. OEE determined for the machines which are M-offset, speed master102/1 and GTO-15 that are found in offset printing section. Accordingly, figure4.5 below shows OEE of each machine for 12 month

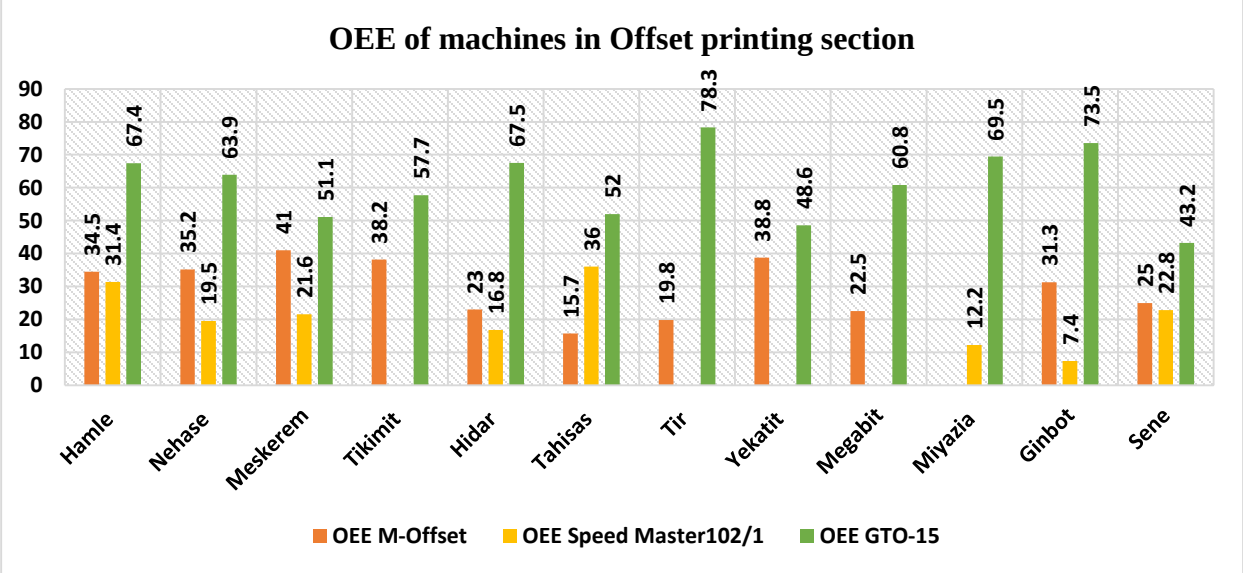


Figure 4.5: OEE of different machine in offset printing section

In the above figure4.5 the bar chart clearly seen that OEE of machines in offset printing section. From the result OEE of each machine shows increasing and decreasing trend across the months. From OEE calculation the maximum and minimum OEE is 78.3 and 7.4 respectively. According to (Mentesinot, 2017)(Hanssen, 2002) an overall 85% benchmark OEE is considered as world-class performance. However, as per the above figure5.5 OEE of the three machines which are M-offset, speed master102/1 and GTO-15 is less than the benchmark OEE that world class performance considered. From OEE result of machines in offset printing section, we can conclude that Equipment's overall operational performance is very low. This low OEE value

implies that the company maintenance performance is very low due to the reason that OEE is one of the indicators of maintenance performance.

For the machines which are speed master74/2, sakurai and sakurai 266-1 and found in offset printing section, OEE determined in the figure4.6 below:

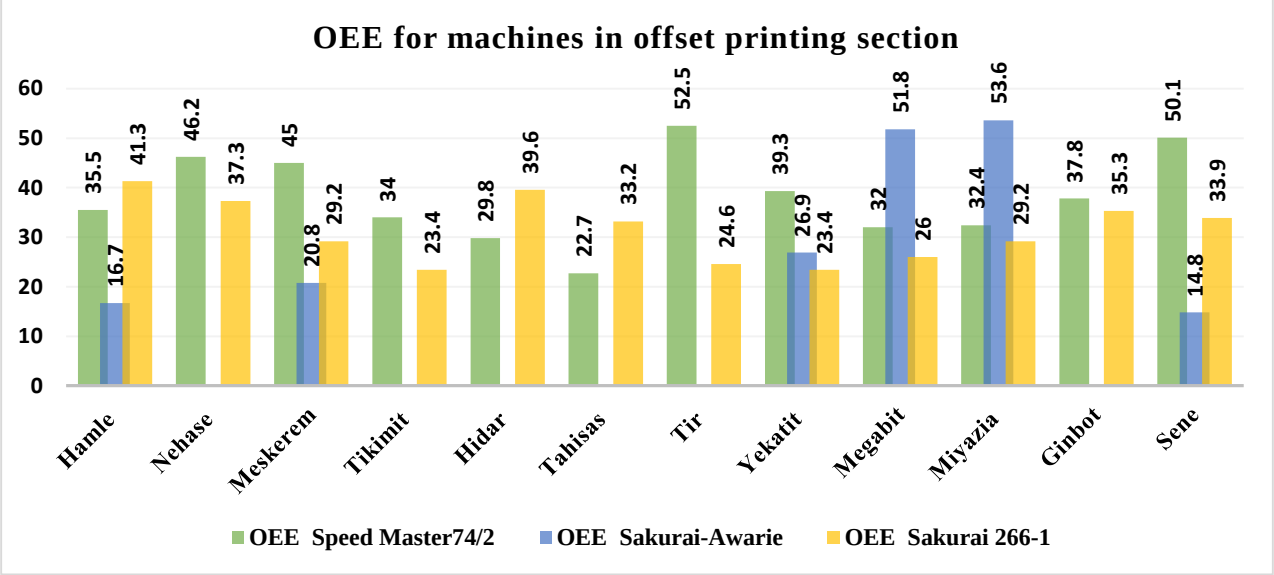


Figure 4.6: OEE for machines in offset printing section

In the above figure4.6 OEE of machines in the offset printing section presented in the chart. From the result of OEE determined, the highest OEE is 53.6 % and the lowest OEE is 14.8 %, which is Sakurai machine. Based on the result shown in the figure4.6, most of OEE of machines determined for each month shows below 50%. This indicates all the machines are not met the OEE benchmark that world class performance considered. Accordingly the finding from the value obtained implies that there is a poor maintenance performance in the company.

The other three machines in the offset printing section which are GTO-46, M-offset-031 and GTO-new, OEE determined and data used for OEE calculation is attached on Appendix.

In the figure4.7 below the chart clearly shows OEE of machines in the offset printing section for 12 months.

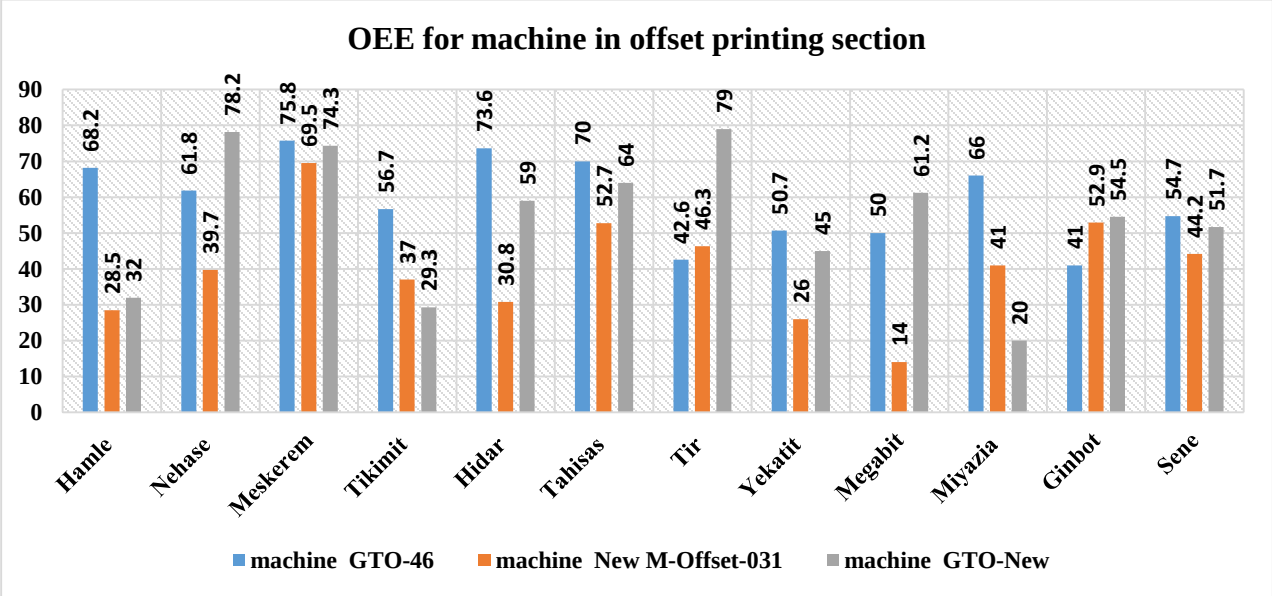


Figure 4.7: OEE for machines in offset printing section

From the figure4.7 above, the result appears that OEE of machines have increasing and decreasing trend with minimum and maximum OEE value of 14% and 79% respectively. This value is still far from the World Class OEE value of 85% and from the result of OEE calculated, there is no single machines that met the world class benchmark OEE. This low OEE value of machines indicated that there is low maintenance performance in the company since OEE is one of the maintenance performance indicators.

b) Wave offset printing section

In the wave offset printing machines OEE determined for the four machines which are solna 1, solna2, Wive546 and Wive578 and the data used for the calculation of OEE is attached in the Appendix.

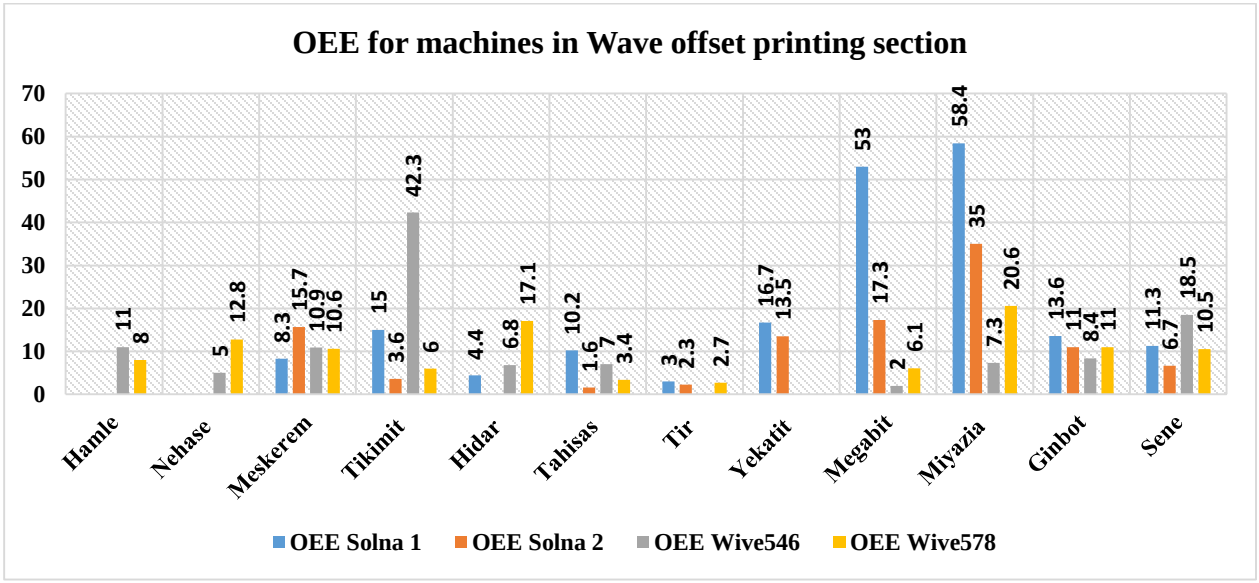


Figure 4.8: OEE of machines in wave offset section

As per the chart shown in the above figure4.8, the result clearly reveals that OEE value is very low that most of the machines calculated OEE result fall below 20%. The maximum OEE result determined is 58.4% which is far from the world class performance OEE benchmark standard 85%.

c) Letterpress printing section

In the letterpress printing section for the machines OEE calculated based on the data obtained from the company and all the data used including the calculation attached in the Appendix.

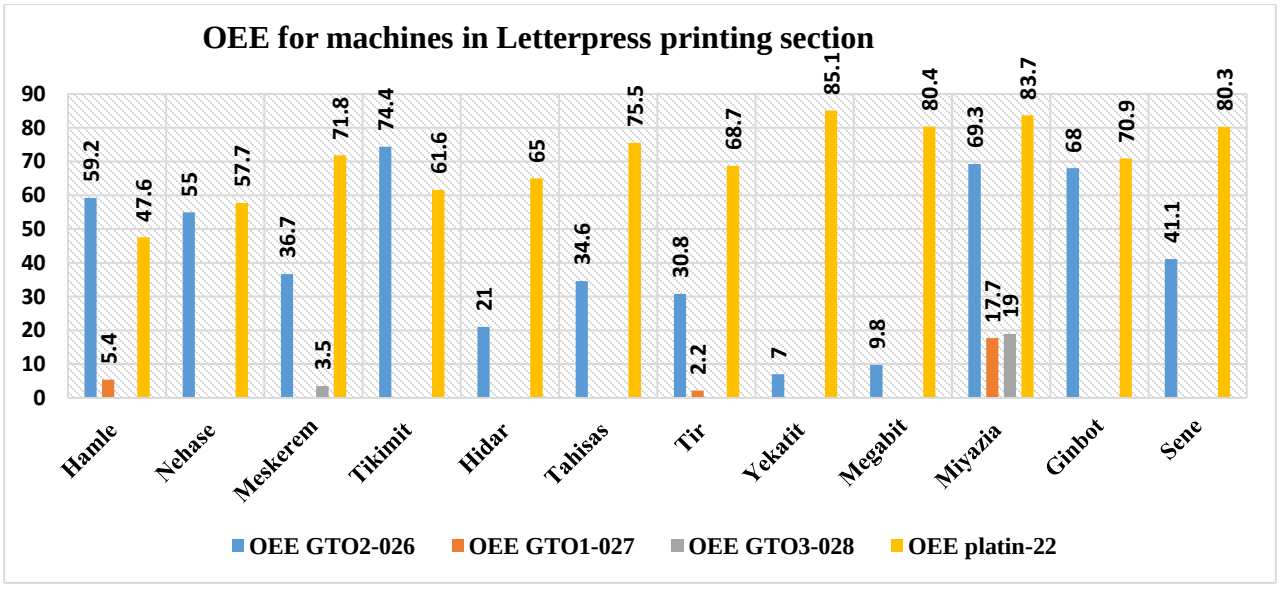


Figure 4.9: OEE of machines in letterpress printing section

From the figure4.9 above the OEE result shows increasing and decreasing trend throughout the months in the year 2017/2018. From the result only one of the machines called Platin-22l met the world class OEE benchmark 85% in one of the month but during the other months the OEE result of this machine couldn't met the world class standard. However, still the OEE results of the machines are very low most of the machines OEE fall between 20 and 70 %.

GTO2-026 machines shows increasing and decreasing trend within 12 months; the highest and lowest value of OEE for this machine is 74.4 and 7 respectively.

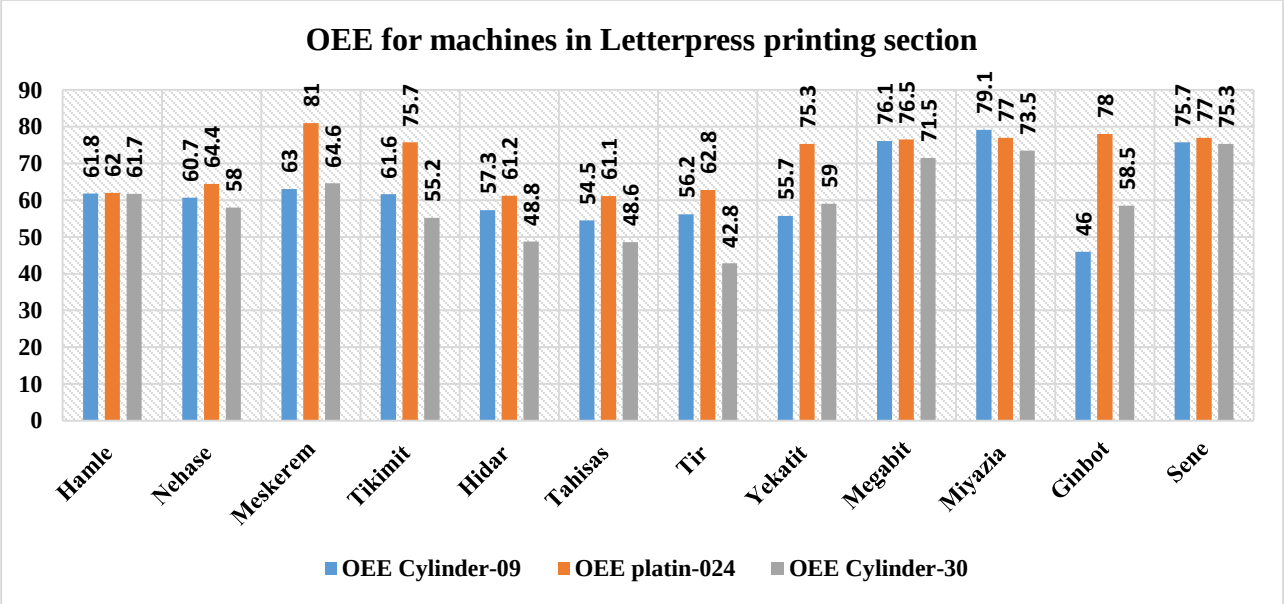


Figure 4.10: OEE of machines in Letterpress printing section

From the figure4.10 above the result reveals that OEE of machines are does not meet the world class OEE benchmark which is 85%. The maximum and the minimum OEE result is 81% and 42.8% respectively. However, most of the machines OEE results fall between 40% and 80%.

d) Security printing section

In the security printing section, OEE calculated based on the data obtained from the company and all the data used including the calculation attached in the Appendix.

In the figure4.11 below the chart clearly shows calculated OEE of machines for each month.

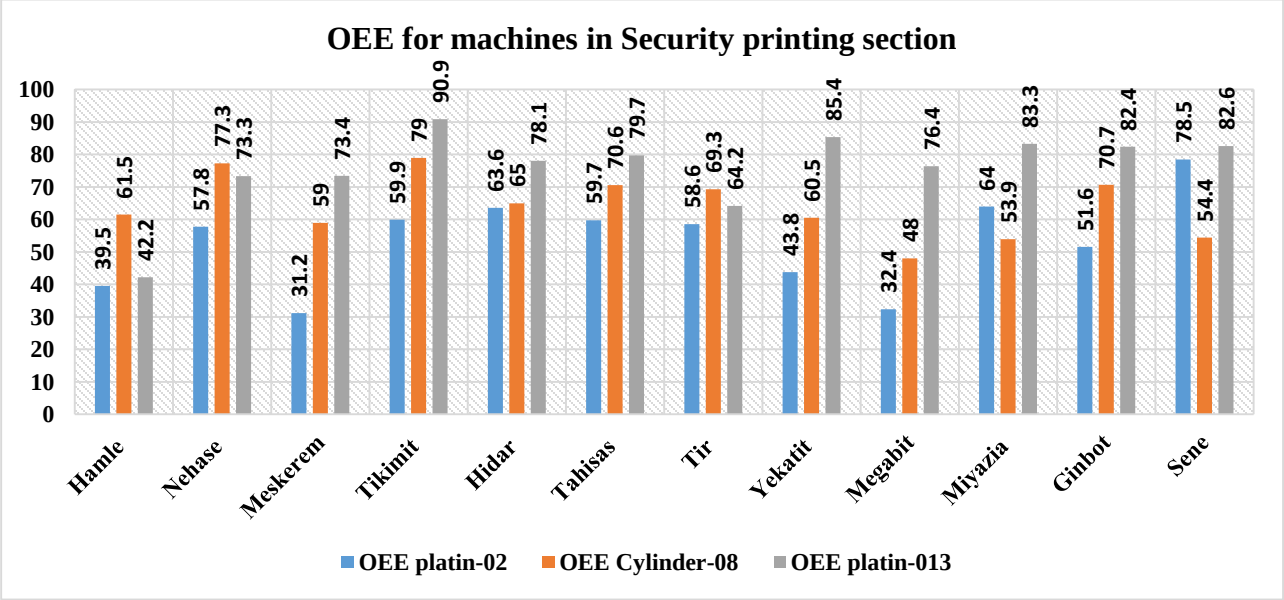


Figure 4.11: OEE for machines in security printing section

From the figure4.11 above, the chart reveals OEE determined for the three machines in the security printing section. As per the result the maximum and the minimum value of OEE is 91% and 31.2% respectively. From this one of the machines called platin-013 met the world class OEE standard with the value of 91% in one of the month but still this machines fall below the standard in the other months.

In the figure4.12 below OEE of machines in the security printing section presented.

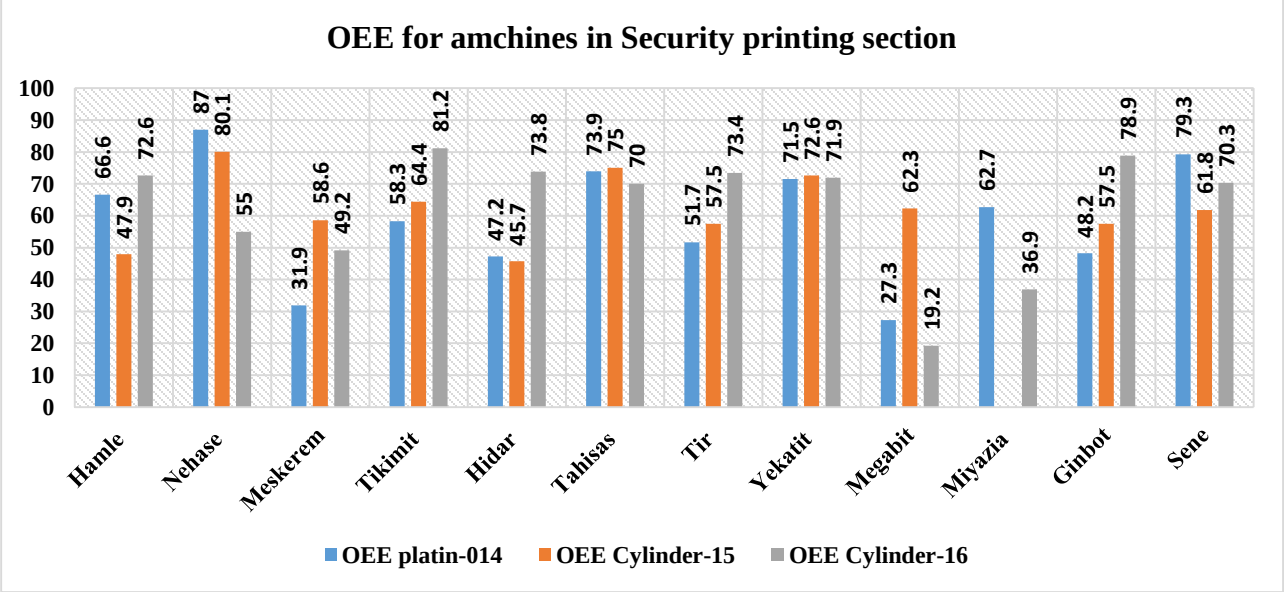


Figure 4.12: OEE for machines in security printing section

As per the result presented in the figure4.12 above, the maximum and the minimum OEE value of platin-014 machine is 87% and 27% respectively. The maximum and the minimum OEE value of cylinder-014 machine is 80% and 46% respectively. For the machine called cylinder-16, the maximum and the minimum OEE value is 81% and 19% respectively. Accordingly from the OEE result of the machines only one of the machines met the world class standard of OEE benchmark for only one month but falls below the standard of OEE in the other remaining months. Regarding the other two machines OEE result none of the machines are met the OEE benchmark standard.

In the figure4.13 below OEE of machines in the security printing section is presented for the year 2017/2018.

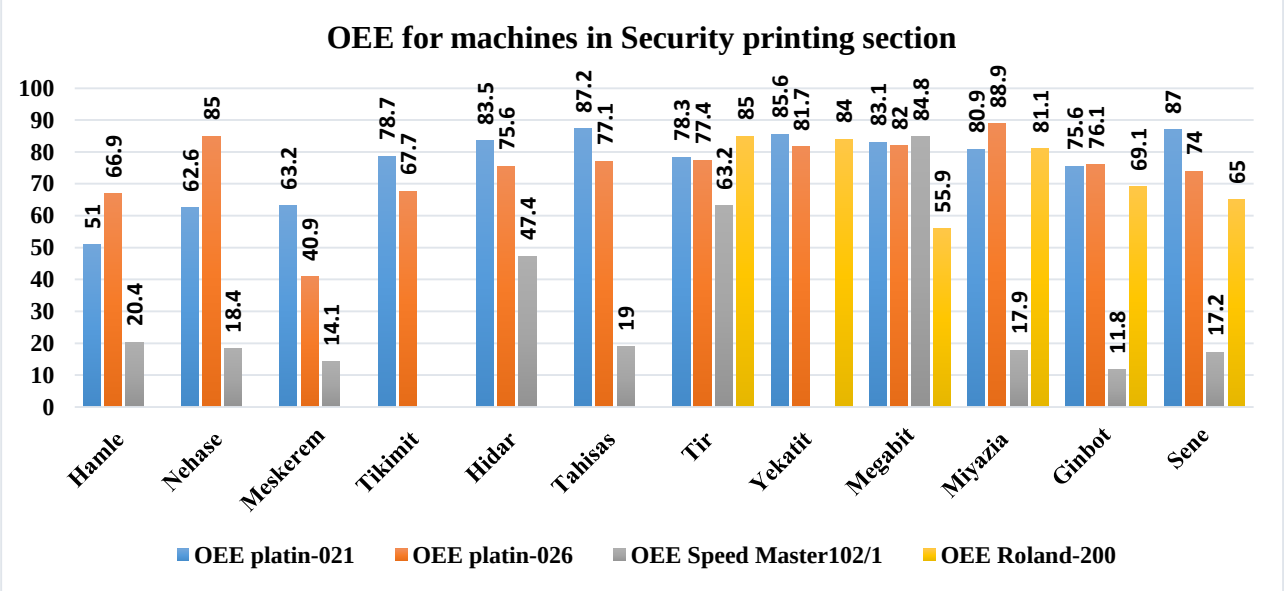


Figure 4.13: OEE for machines in security printing section

In the figure4.13 above, OEE result of machines in the security printing section reveals that some machines OEE values are below the world class benchmark standard and also some machines met the standard. Accordingly the maximum and the minimum OEE value is 89% and 12% respectively.

In the figure4.14 below OEE for machines in security printing section is presented.

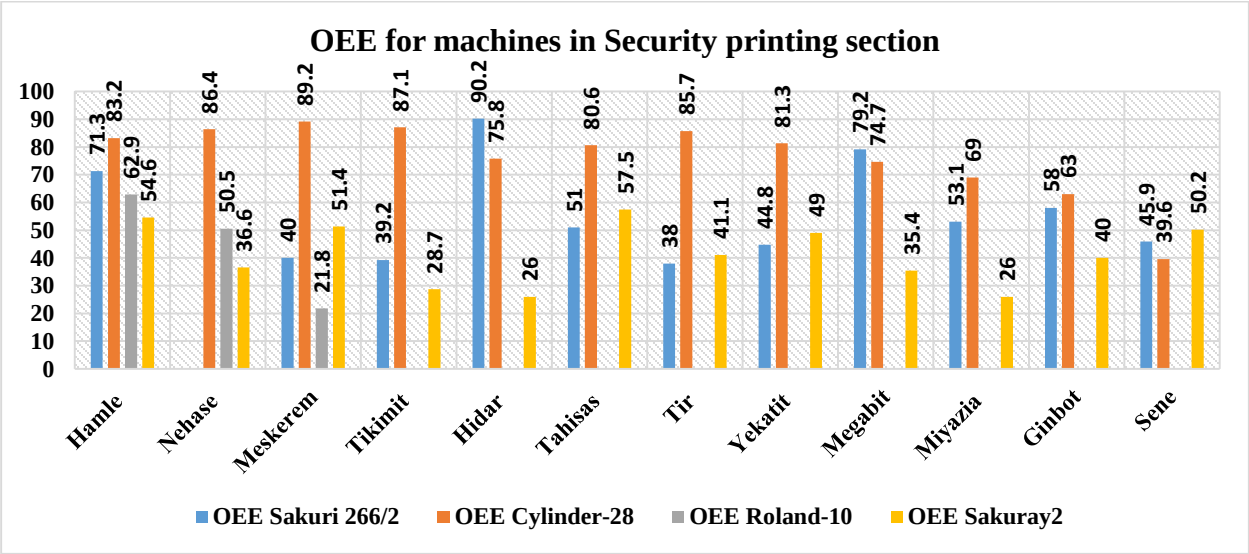


Figure 4.14: OEE of machines in security printing section

In the above figures4.14 of OEE for machines in the security printing section presented, according to the result found the OEE values shows an increasing and decreasing trend throughout the months. The maximum and the minimum OEE value is 90% and 22% respectively. However, two of the machine met the world class benchmark standard of OEE value for one of the month but they get fall below the standard in the other months.

4.4.2. Summary of Machine performance Analysis using OEE

To analyze the machine performance, determine OEE for the machines is one of the methods accordingly; OEE has been calculated for the machines which are found in four printing section such as offset printing section, wave offset printing section, letterpress section and security printing section. From the calculated result found comparison has been done with the world class OEE benchmark standard 85%. However the result obtained from the calculated OEE reveals that the machine performance of the company is very low.

4.5. Cause and Effect Analysis

As per the above calculated OEE for each machines which are found in different sections, the findings reveals that there is low OEE of machines when it's compared with the world class OEE benchmark standard accordingly, in the figure4.15 below cause and effect diagram presented for root cause and effect analysis of low OEE of machines.

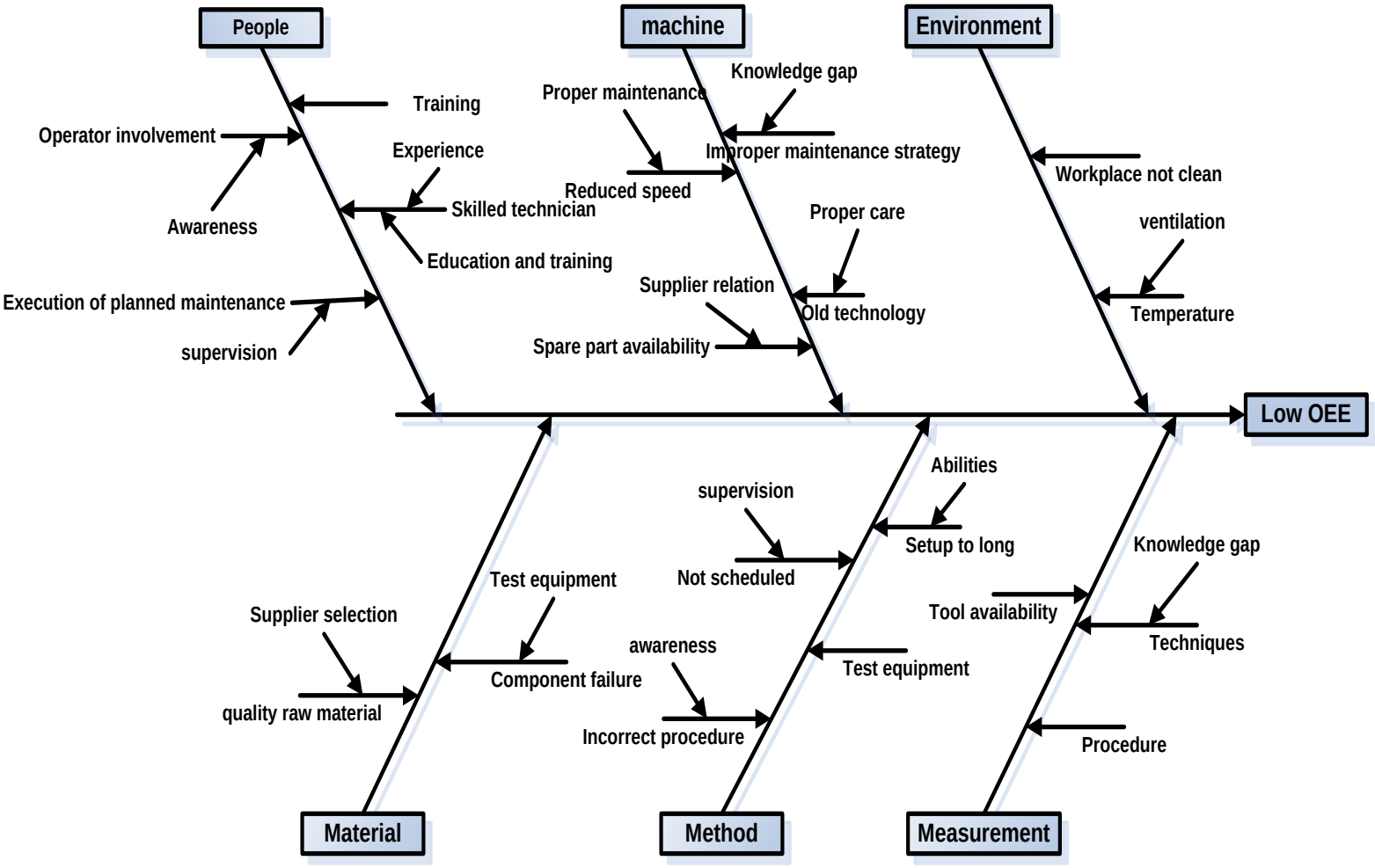


Figure 4.15: Cause and effect chart for Low OEE

4.6. Information on critical success factors (CSF) and Maintenance performance

As per the distributed questionnaires to gather information regarding the critical success factors with respect to maintenance performance, the respondents response presented in the table4.6 below:

Table4.6: Respondent percentage rate

No.	Items	Strongly Disagree (%)	Disagree (%)	Unsure (%)	Agree (%)	Strongly Agree (%)
Information on Organizational Factors (Of)						
Of1	You have good communication with the shop floor workers regarding maintenance activities and related issues?	0	22.2	22.2	55.5	0
Of2	Are the top management involve in achieving maintenance performance?	0	75	0	25	0
Of3	Are the top management support maintenance technicians and Production operators to work together on maintenance issues?	30.5	42.9	15.7	10.7	0
Of4	Your company gives training concerning new technologies frequently to maintenance technicians and operators?	50.4	43.8	4.1	1.6	0
Of5	Your company gives training to operators develop skills to routinely maintain equipment and identify emerging problems?	50.8	43.1	6	0	0
Of6	Are the maintenance strategy (i.e. preventive maintenance, corrective maintenance, reactive maintenance & predictive maintenance) used in the company effective?	19.8	28.1	14	38	0
Of7	Your company has strong and long term relation with suppliers (i.e. machine suppliers and spare part suppliers) ?	0	4/9	2/9	3/9	0
Of8	Your company selected equipment's supplier based on pre-determined criteria?	22.2	44.4	22.2	11.1	0
Of9	You and your supplier share technical information with each other as necessary?	11.1	44.4	22.2	22.2	0
Of10	Is there all the necessary spare parts are available in your company stock?	22.3	52	7.4	18.2	0
Information on Human Factors (Hf)						
Hf1	Are maintenance technicians have strong skill and knowledge in performing maintenance activities?	11.6	29.7	14.8	32.2	11.5
Hf2	You think skills of maintenance technician's affect maintenance performance of your company?	0	0	11.1	55.5	33.3
Hf3	Are production operators involve in performing maintenance activities i.e. cleaning, lubricating inspection and adjusting equipment's?	22.3	40.5	10.7	17.3	9.1

Hf4	Are others departments integrate to work together with maintenance department?	23.1	47.1	14	10.7	4.9
Hf5	Are production operators are motivated in performing maintenance activities?	23.9	50.4	19.8	5.8	0
Hf6	You are motivated in performing maintenance activities and in solving any company problems?	19.8	28.9	38.8	9.1	3.3
Hf7	You think you are motivated in performing maintenance activities for the machine that you operate by yourself?	14	24.8	33.8	19.8	7.4
Information on Technology Factors (Tf)						
Tf1	Is the current technology used in the company have an impact on the maintenance performance?	0	15.7	18.2	51.2	14.8
Tf2	Are the current equipments used for production effective?	12.4	26.4	38.8	22.3	0
Information on Resource Factors (Rf)						
Rf1	Are the technical manuals are available for all machines?	26.4	46.3	22.3	4.9	0
Rf2	You have the ability to understand the technical manuals?	0	20.5	38.4	33	8
Rf3	You think unavailability of manuals affects in performing maintenance activities?	6	9.5	16.4	43.9	24.1
Rf4	Are the necessary test equipment's and tools available for maintenance services?	22.3	52.9	17.3	7.4	0
Information on maintenance performance (MF)						
MP1	Are machines repetitively unavailable due to unplanned stoppage/failure?	0	10.7	14	48.7	26.4
MP2	Is the level of machine downtime affect the planned production time?	2.5	5.8	14	50.4	27.3
MP3	Is there a frequent unplanned machine failure in your company?	0	7.4	9.1	36.3	47.1
MP4	Your company immediately repairs machines that failed due to unplanned stoppage and restore to the previous condition?	25.6	51.2	14	9.1	0
MP5	Is the performance of machines in your company effective?	12.4	26.4	38.8	22.3	0
MP6	Is the planned maintenance that is carried out effective?	19.8	28.1	14	38	0

4.6.1. Correlation Analysis

To determine the strength of two variables, correlation analysis used to measure how variables are related. In this research to study the significant impact of the critical success factors of TPM towards maintenance performance, correlation analysis has conducted. Correlation computes a set of variables and display in a matrix. Accordingly in this study the independent variables are organizational factors, human factors, technological factors and resource factors. The dependent variable is maintenance performance. However, in determining the significant strength between the independent variable and dependent variable, a Pearson coefficient (r) was used in this

research. A Pearson correlation matrix indicates the strength, and significance of the bivariate relationships of all the variables.

The correlation coefficient result obtained from SPSS output with respect to the independent variable with the dependent variable presented in the table4.7 below:

Table4.7: correlation between variables

Correlations

		MP	OF	HF	TF	RF
MP	Pearson Correlation	1	.458**	.910**	.961**	.853**S
	Sig. (2-tailed)		.000	.000	.000	.000
	N	121	121	121	121	121
OF	Pearson Correlation	**.458****	1			
	Sig. (2-tailed)	**.000**				
	N	**121**	121			
HF	Pearson Correlation	**.910****		1		
	Sig. (2-tailed)	**.000**				
	N	**121**		121		
TF	Pearson Correlation	**.961****			1	
	Sig. (2-tailed)	**.000**				
	N	**121**			121	
RF	Pearson Correlation	**.853****				1
	Sig. (2-tailed)	**.000**				
	N	**121**				121

**. Correlation is significant at the 0.01 level (2-tailed).

Source: SPSS output

As per the result obtained from the SPSS output of correlation between the independent variables and dependent variable in the above table4.7 the interpretation presented as follows

- **Relationship between Organizational factors and maintenance performance**

Here, concerning the relationship between organizational factor and maintenance performance in the case company, the result found in the table4.7 above reveals that there is a strong, positive and significant relation between organizational factor and maintenance performance with (significant value of Pearson correlation coefficient (r) = 0.458**, at $p<0.01$) this means it is statistically significant with a confidence of 99 percent. For that reason, the result indicates that

enhancing organizational factors will lead in improving maintenance performance of the company.

According to the finding from correlation coefficient organizational factors has a positive significant impact in affecting maintenance performance of the company, hence each sub-factors of the organizational factors such as top management involvement, training and education, maintenance strategy used, supplier relation and spare part availability also has a positive significant impact in affecting the maintenance performance of in the company.

As per the respondent regarding one of the sub-factors of organizational factors which is maintenance strategy of the company

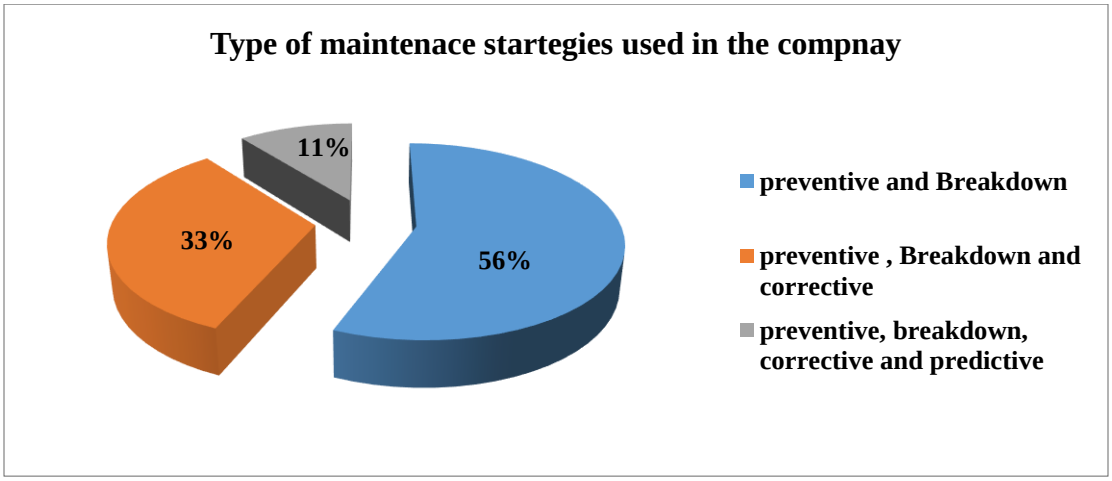


Figure 4.16: Type of maintenance strategies used in the company

From the figure4.16 above, 56.2% of the respondents replied that in the company only used the two maintenance strategies such as preventive and breakdown maintenance. 33% of the respondents replied that preventive, breakdown and corrective maintenance are used in the company the other respondents said that predictive maintenance also used in the company beside the three maintenance strategies. As it was observed from the report of the company the only maintenance strategies that are used are preventive and breakdown maintenance, As per the respondent reply even though there are a preventive and corrective maintenance strategies, as it was observed mostly breakdown maintenance occurs this clearly indicated in the downtime analysis. Accordingly this shows there is a problem with preventive maintenance schedule because, if the preventive maintenance was successful executed breakdown would not happen frequently.

Regarding frequency of training and education given to the maintenance technicians and production operators in the company,

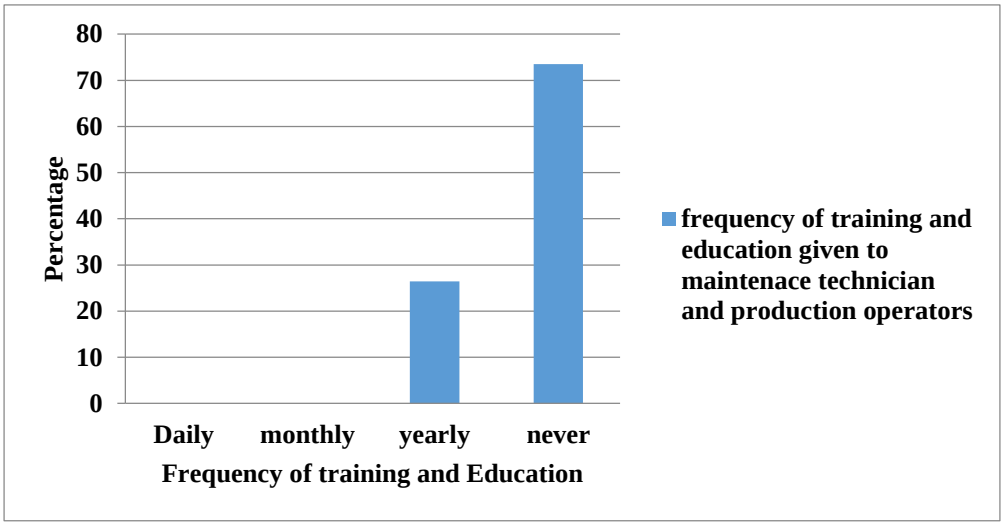


Figure 4.17: Training and education frequency given to maintenance technician and production operators

From the figure4.17 above about 73.5% of the respondents replied that there is no training and education is given in the company the other 26.4% respondents said that in yearly basis training and education is given to the maintenance technician and production operator. This imply that majority of the respondents replied that there is no training and education that were given in the company. From this it's concluded that the company has not training schedules to improve the skill of the maintenance technicians and production operators.

- **Relationship between Human factors and maintenance performance**

Regarding the relationship between human factors and maintenance performance in the company, the result in the table4.7 above reveals that there is a strong, positive and significant relation between human factors and maintenance performance with the larger value of the correlation Pearson coefficient (r), ($r=0.910^{**}$, $p<0.01$), according to the result found the significant relationship between the two factors clearly indicates that improving one of the factors will leads in improving the other also.

The result obtained from correlation coefficient illustrate that there is a positive significant relationship between human factors and maintenance performance of the company; this means the sub-factors under human factors such as level of skill and experience, employee's involvement and employee's motivation also has a positive significant impact in affecting the maintenance performance of the company.

From the survey finding concerning the level of company staff from top management to shop floor workers involvement in improving maintenance performance of the company

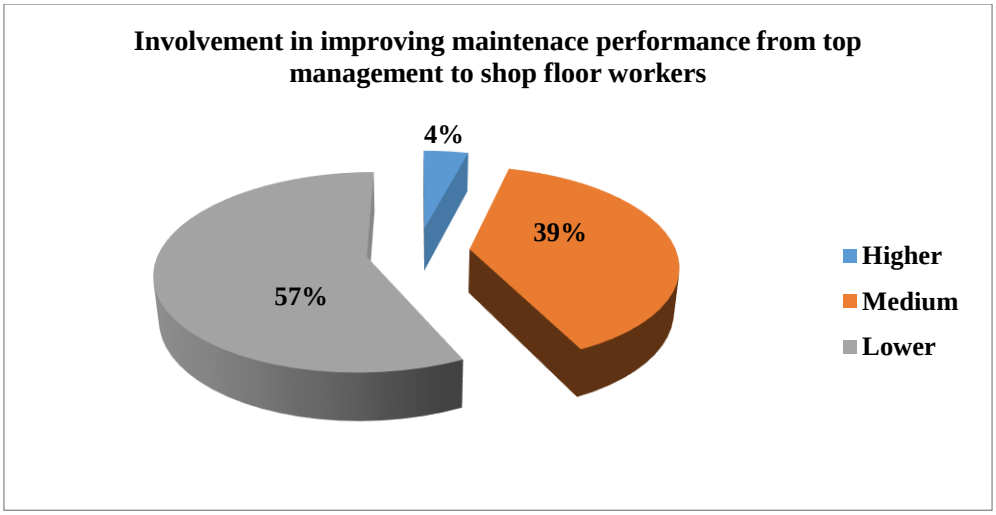


Figure 4.18: Involvement in improving maintenance performance from top management to shop floor workers

As per the figure4.18 above, from the total participants 57% of the respondents replied that the involvement from top management to shop floor workers in improving maintenance performance is lower where as 47% said that involvements is medium and the other responds that there is higher involvements. This indicated that the involvement from top management to shop floor is very low and this leads a high significant in affecting maintenance performance of the company.

Regarding to the involvement of production operators in performing maintenance activities:

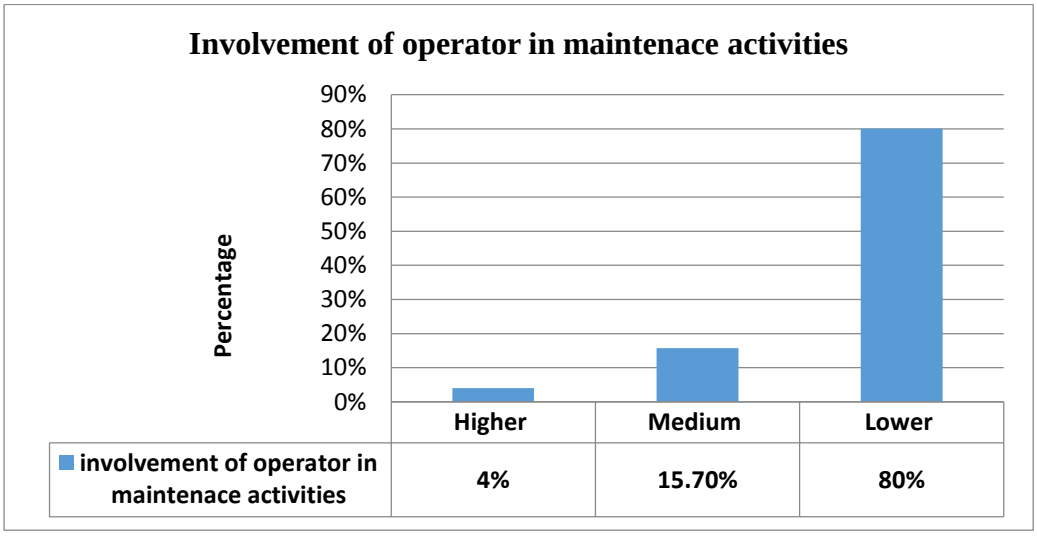


Figure 4.19: Involvement of production operators in performing maintenance activities

As per the survey respondent in the above figure4.19, about 80% of the respondents answered that involvement of production operators in performing maintenance activities is lower, 15% of the respondents replied medium and the rest of the respondents replied that operator's involvement is higher in performing maintenance activities. From the percentage of respondents found from the survey, regarding involvement of operators in maintenance works is extremely very low this reveals that the impact of involvement of operators in maintenance performance is very high.

Considering the level of Skill and Experience of the maintenance technicians

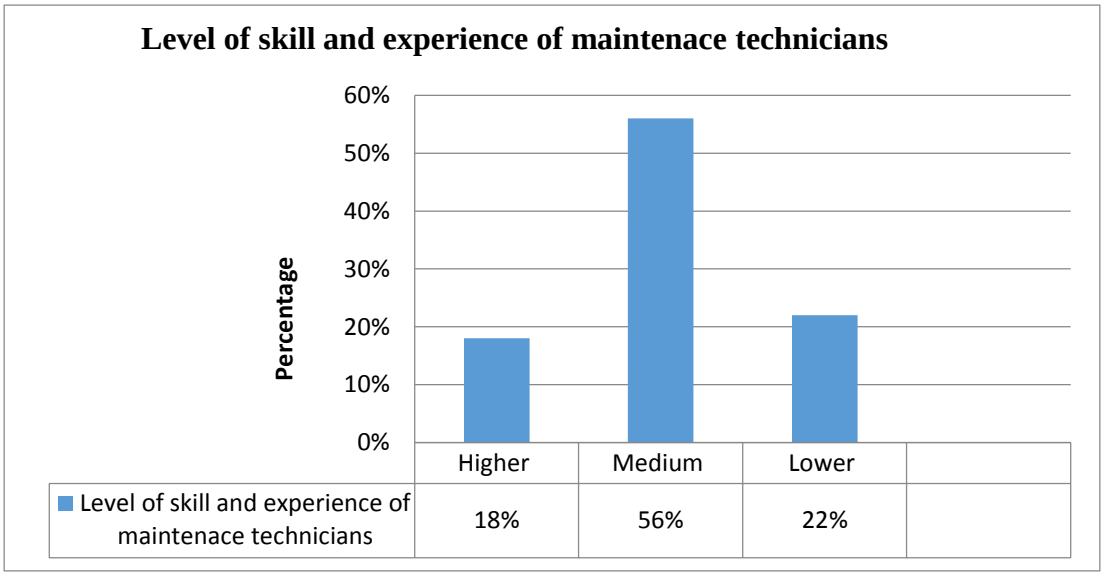


Figure 4.20: Level of skills and experience of maintenance technician

From the above figure4.20 about 56% of the respondent replied that the skill and experience of maintenance technician in handling maintenance activities is medium, 25% of the respondents replied that lower where as 18% answered technicians skills and experience is higher. This clearly indicates that maintenance technician's skills and experience has a high significant impact in affecting maintenance performance of the company.

- **Relationship between Technological factors and maintenance performance**

Considering the relationship between technological factors and maintenance performance of the company, the result in the table4.7 above shows that there is strong, positive and significant relation between technological factor and maintenance performance with large value of Pearson correlation coefficient (r) ($r=961^{**}$, at $p<0.01$), this means its statistically significant with

confidence of 99%. From the outcome of correlation, it's concluded that enhancing technological factors will lead in improving of maintenance performance of the company.

- **Relationship between Resource factors and maintenance performance**

Concerning the relationship between resource factor and maintenance performance in the case company, the result found in the table4.7 above reveals that there is a strong, positive and significant relation between resource factor and maintenance performance with (significant value of Pearson correlation coefficient (r) = 0.853^{**}, at $p<0.01$) this means it is statistically significant with a confidence of 99 percent. Accordingly, the result indicates that enhancing resource factors will lead in improving maintenance performance of the company.

Correlation Result and Discussion

As per the result found from Pearson correlation coefficient(r), all the four factors such as organizational factors, human factors, technological factors and resource factors has strong, positive and significant relation with maintenance performance of the company. This clearly indicates that improving of those four factors will lead in enhancing the company maintenance performance. Accordingly, all the four factors has to be the critical areas in the company that to enhance the maintenance performance.

4.6.2. Regression Analysis

Regression analysis is a set of statistical processes used to estimate the relationship among variables that to understand which among the independent variables are related to the dependent variable. Accordingly, in order to see the strong contribution of the independent factors in affecting the maintenance performance, regression analysis has been used.

The result found from the regression analysis presented as follow

Model summary

The model summary contain one model, in which RF, OF, TF and HF are used as predictor

Table 4.8: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.991[a]	.982	.981	.73899	.982	1563.082	4	116	.000

a. Predictors: (Constant), RF, OF, TF, HF

Source: SPSS outcome

The above table4.8 provides the *R*, R^2, adjusted R^2, and the standard error of the estimate, which can be used to determine how well a regression model fits the data. Accordingly, in the above table4.8 column R are the value of multiple correlation coefficients between the predictors and the outcome, the value of R shows larger positive values with 0.991 this indicates that there is a stronger relationship between the predictors and the outcomes. The next column gives a value of R^2, which is a measure of how much of the variability in the outcome is accounted for by the predictor therefore R^2 is 0.982 and about 98.2% of the variation in maintenance performance is explained by resource, organizational, technological and human factors.

ANOVA (Statistical significant)

The ANOVA table below gives an *F*-test to determine whether the model is a good fit for the data

Table 4.9: ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3414.437	4	853.609	1563.082	.000[a]
	Residual	63.348	116	.546		
	Total	3477.785	120			

a. Predictors: (Constant), RF, OF, TF, HF

b. Dependent Variable: MP

Source: SPSS output

In the above ANOVA table4.9 the F-test determine whether the overall regression model is a good fit for the data. The table reveals that the independent variables statistically significantly predict the dependent variable, F (4, 116) = 1563.08, $p < .0001$ (i.e., the regression model is a good fit of the data).

Model parameters

The beta coefficient tells how strongly the independent variable associated with the dependent variable. Accordingly the result found from the regression analysis presented below:

Table 4.10: Coefficients

Model		Un-standardized Coefficients		Standardized Coefficients	T	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	4.196	.340		12.355	.000			
	OF	-.372	.030	**.283**	-12.212	.000	.458	-.750	-.153
	HF	.692	.042	**.762**	16.330	.000	.910	.835	.205
	TF	.458	.130	**.156**	3.526	.001	.961	.311	.044
	RF	.540	.038	**.314**	14.157	.000	.853	.796	.177

Source: SPSS output

To compares the strength of the effect of each individual independent variable to the dependent variable, a standardized beta coefficient used. If there is higher value of the beta coefficient, the stronger the effect. From the above coefficient table4.10 since the large value of beta coefficient in an independent variable has the more important determinant in predicting the dependent variable, the larger standardize beta value from all independent variables are human factor with 0.762 value. This can clearly indicated that human factor has strongly significant in affecting the maintenance performance of the company relative to the others independent variables (factors). The beta value for the others independent variables such as resource factors, organizational factors and technological factors are 0.314, 0.283 and 0.156 respectively. This means resource factor is the second strongly significant factors next to human factors in affecting the maintenance performance. The remaining factors such as organizational factors and technological factors have the third and fourth significant in affecting the maintenance performance of the company respectively.

The significant column of regression coefficients tells us that that independent variable has a significant contribution to predict. Accordingly, coefficients of predictor variables are statistically significant by looking at the p-value of the t-test for each predictor ($p<0.01$), its seen that organization factors, human factors, technological factors and resource factors contributes to the model.

Summary of Regression Result and Discussion

According to the result found from the regression analysis, it is indicated that all of the independent variables such as organizational factors, human factors, technological factors and resource factors are statistically significant in contribution to predict the outcomes, maintenance

performance. Regarding the important determinant in predicting the dependent variable from all the independent variables, human factors has the most significant in affecting the dependent variable, maintenance performance with larger value of 0.762. The other factors based on decreasing order ranked the second, third and fourth factors next to human factors are resource factor, organizational factors and technological factors respectively. This lead that all the factors have a significant contribution in enhancing the maintenance performance of the company but human factors has the important dominant factors with high contribution.

4.6.3. Summary of overall research hypothesis

In the table4.11 below the overall research hypothesis summary presented, as per the researcher started the study from formulation of hypothesis considering the relationship between the critical success factors and maintenance performance. The analysis has been supported using correlation and regression analysis to test the significant impact of the independent to the dependent variables. From the analysis, the finding reveals that all the independent variables (critical success factors) have a positive significant impact in affecting the dependent variable (maintenance performance) of the company. This means all the four hypotheses are accepted that the researcher has formulated.

Table 4.11: summary of overall research hypothesis

Hypothesis	Result	Reason
H0: An organizational factor has not a positive impact on maintenance performance of the company. H1: An organizational factor has a positive impact on maintenance performance of the company.	H0: Rejected H1: Accepted	ß=0.283, p<0.01
H0: A human factor has not a positive impact on maintenance performance of the company. H2: A human factor has a positive impact on maintenance performance of the company.	H0: Rejected H2: Accepted	ß=0.762, p<0.01
H0: A technological factor has not a positive impact on maintenance performance. H3: A technological factor has a positive impact on maintenance performance.	H0: Rejected H3: Accepted	ß=0.156, p<0.01
H0: A Resource factor has not a positive impact on maintenance performance. H4: A Resource factor has a positive impact on maintenance performance.	H0: Rejected H4: Accepted	ß=0.314, p<0.01

4.7. Summary of Research Findings

The researcher has been presented the result finding of the study with discussion in the above section accordingly here are the summaries:

- From the data presentation the finding about the registered downtime in the company reveals that there is high occurrence of downtime that leads interruption to perform planned production plan based on the schedules.
- According to (Chandran, 2015) OEE has become the accepted indicator to assess, that how plants actually manage their most expensive asset, the equipment, to produce saleable goods, with minimum losses and wastes. As per the machine performance analysis the finding obtained from the calculated OEE for the machines that are found in four printing section has very low. The OEE percentage calculated is used to track the improvement or downfall in equipment effectiveness over a period of time (Ramachandra et al., 2016).
- The relationship between selected critical success factors and maintenance performance has been studied and all the independent variables (critical success factors) such as organizational factors, human factors, technological factors and resource factors has strongly positive significant in affecting the dependent variable (maintenance performance). From this it's concluded that the significant factors are the critical areas that lead in enhancing the maintenance performance of the company. Accordingly giving more attention to these factors will directly help to increase the performance of maintenance.
- From all the independent variables (critical success factors), human factors is one of the dominated factors that have high contribution in affecting dependent variable (the maintenance performance) of the company from other factors. This means that special attention has to be given to this factor to enhance the maintenance performance of the company.
- From the survey finding concerning level of the company staff from top management to shop floor workers involvement is very lower in improving maintenance performance of the company.
- According to the finding from the survey there is low involvement of production operators in performing maintenance activities. According to (Kedar & Borikar, 2016) the importance of total employee involvement is based on the beliefs that shop floor operators have the most hands on experience with the machines they operate daily. This means establishing of a

sense of ownership to the operators in their daily operating equipment will guarantee the machines to be clean and maintained.

- The finding from the survey reveals that there is no training and education given to the maintenance technicians and production operators in the company frequently.
- In relation to the level of maintenance technician skill and experience in handling maintenance activities problems, majority of the respondents replied that their skill and experience is medium.

4.8. Relationship between selected critical success factors with TPM pillars

According to the result obtained from analysis in the above, the selected four critical success factors (including the sub-factors) has a positive significant contribution in affecting the maintenance performance of the company. It's significant also supported through survey finding from the respondents with respect to the involvement of operators in performing maintenance activities, top management involvement, frequency of training and education given to the maintenance technicians, the level of skill and experience of technicians. This indicates that all the four factors are important since the significant is strong; this means addressing those factors will leads improvement of the maintenance performance. Accordingly, the researcher has done relationship to interconnect the critical success factors with TPM pillars. While selecting the pillars to each factors, the compatibility supported considering different researchers.

Accordingly, in the table4.12 below the selected pillars with respect to each CSF'S description presented

Table4.12: Relationship between CSFs and TPM pillars

No.	Selected CSF	Selected TPM pillars	Remark
1.	**Organizational Factors**		
	➢ Top management involvement		As per the result obtained top management involvement has a significant impact in affecting maintenance performance of the company. This means Top management has to create an environment that support and improve the way that systems are performed. According to (Chandran, 2015) Top management cooperation is the concrete factor that makes the efforts of TPM implementation a great success.
	➢ Training and Education	Education and training	Training and education is one of the critical areas that has a significant contribution in affecting maintenance performance of the company. According to (Prashanth Pai, Ramachandra, Srinivas, & Raghavendra, 2018) Total Productive Maintenance (TPM) is considered to be a widely accepted strategy for improving the performance of maintenance activities. This indicates that addressing these critical areas through TPM leads to enhance the maintenance performance. Education and training is one of the pillars that are used to practice TPM According to (Shaaban & Awni, 2014) this pillar is concerned with developing the right program to identify and introduce required skills for the organization. Increased skills and performance of all personnel throughout the organization is essential for the successful implementation of TPM (Mwanza & Mbohwa, 2015). This indicates that practicing education and training pillar will enhance the knowledge of the peoples who are engaged in the production and maintenance activities of the company.
	➢ Maintenance strategy used	Planned maintenance and quality maintenance	Selecting appropriate maintenance strategies along with the equipment characteristics is one of the critical areas that the company should have to give emphasized attention. As per the findings found that maintenance strategy used in the company has a significant impact in affecting maintenance performance of the company. Addressing this critical factor will improve the maintenance performance, with this regards Planned maintenance and quality maintenance are the selected pillars that can be used to address the critical factors of the company. According to

			(Shaaban & Awni, 2014) Planned maintenance pillar focuses on maintenance activities and how to create optimum mix of maintenance activity types (routine, preventive, and predictive) in order to eliminate breakdown losses at minimum cost. It follows a structured approach to establish a management system that extends the equipment reliability. This indicates practicing this pillar will lead in improving maintenance performance. Quality maintenance also another pillar that improve maintenance efficiency and effectiveness. As (Sharma et al., 2012) mentioned Quality maintenance is achieved by maintaining conditions within specified standards, inspecting and monitoring conditions to eliminate variation, and executing preventive actions before occurrence of defects or equipment/process failure. It is a cause oriented approach that focuses on preventive action before it happens rather than reactive measures after it happens. Accordingly this pillar will address the issues in relation with maintenance strategy of the company and lead improvement in maintenance performance.
	➢ Supplier Relation	Focused improvement	Creating strong and long term relation with suppliers has the most critical area that companies should give attention. As per the result finding found from the analysis, supplier relation has a significant impact in affecting maintenance performance of the company. This indicates supplier relation is one of the critical factors that lead improvement of maintenance performance. Along with this the selected pillar is focused improvement. According to (Mwanza & Mbohwa, 2015) mentioned focused or Continuous improvement pillar provides a structured, Steam-based approach to drive elimination of specifically identified losses in any process.
2.	Human Factors		
	➢ Level of skill and Experience	Education and training	From the finding obtained Human factors has the most dominated factors that has high significant in affecting maintenance performance of the company rather than others. Under human factors there are sub factors and level of skill and experience is one of the factors. As its know that having a well skilled and experience in performing maintenance activities will leads a great achievement however, the level of skill and experience has a impact on the company maintenance performance dominantly, this shows that special attention has to be given for these critical factors.

			Concerning to the CSF, Education and training is the selected pillar. As (Sharma et al., 2012) mentioned in their study, Education and training is an essential activity in the process of implementation of TPM, since, the effectiveness of whole programme depends on the degree to which the employees understand it and acquire desired operations and maintenance skills. Accordingly, to address the critical area that has a positive significant impact on the maintenance performance of the company which is level of skill and experience, practicing Education and training will leads in improving desired outcome.
	➢ Employees Involvement ➢ Employees motivation	Autonomous maintenance, planned maintenance, Focused Improvement	From the result obtained that employee's involvement is the sub-factor of Human factors and it has a positive significant impact in affecting maintenance performance of the company this indicates that employee's involvement is the critical area that leads to improvement. Accordingly, to address this factor Autonomous maintenance and planned maintenance are the selected TPM pillar. As per (Chandran, 2015) mentioned TPM seeks to involve workers in all departments and levels, from the plant-floor to senior executives, to ensure effective equipment operation. Autonomous maintenance, a key aspect of TPM, trains and focuses workers to take care of the equipment and machines with which they work. It involves the participation of each and every operator, each maintaining his own equipment and conducting activities to keep it in the proper condition and running correctly (Sharma et al., 2012). As (S. N. Seleem, 2018) mentioned total employee involvement, autonomous maintenance that implemented by manufacturing operators, continuous improvement activities, and teams' activities that improve the overall equipment effectiveness (OEE), are the principles embraced by TPM. This all indicated that practicing autonomous maintenance will lead participation of each and every person in the company and also motivate the employees. Along with autonomous maintenance exercising planned maintenance establishes and maintains optimal equipment and process conditions, this improves the quality of maintenance technicians and in turn increases the availability of equipment's.

3.	**Technological factors**		
	➢ Technological status ➢ Equipment Effectiveness	Autonomous maintenance, Planned maintenance and Focused Improvement	From the result obtained organizational factors has one of the significant factors that affects the maintenance performance of the company. This indicates that organizational factor is the critical focus areas to enhance maintenance performance of the company. To address the area and achieve improvement TPM pillars such as autonomous maintenance and planned maintenance is the selected pillars. As (Sharma et al., 2012) mentioned that Autonomous maintenance targets on prevention of equipment deterioration through appropriate operation and daily inspections, restoration and proper management of equipment and establishment of the basic conditions essential to keep up the equipment. This indicated the technological related problems will be addressed with this pillar to improve the effectiveness of the equipment's. Planned maintenance also brings optimal equipment conditions. It also Provide guidance and assistance in autonomous maintenance. According to (Dutta & Dutta, 2016) planned maintenance function is to minimize unplanned failures in a production process. The features are Effective and efficient planned maintenance and TBM (Time Based Maintenance) systems over equipment life cycle and Improving MTBF (Mean Time before Failure), MTTR (Mean time to repair). Accordingly, practicing this two pillars will maximize the effectiveness of the equipment's and improve maintenance performance.
4.	**Resource Factors**		
	➢ Technical manuals ➢ Test equipments and tools	Quality maintenance and Focused Improvement	To achieve maintenance performance, resources for performing maintenance activities have to be provided. Based on the result finding obtained in this research, a resources factor has positive significant impact in affecting maintenance performance of the company. This reveals that resource factors are the critical area that has to be addressed through practicing TPM pillars. Accordingly the selected pillar with respect to this critical success factor is quality maintenance. As (Rajdeep Singh, 2017) stated that quality maintenance focused on the quality of the product through detection free manufacturing it mainly concentrates on the improvement of the equipment in a systematic way. It detects those parts which cause a problem and affects the

			quality of the product. It tries to eliminate the current quality concerns and then move them to possible superiority matters. This indicates that practicing quality maintenance will leads to improve resource related problems and ensure reliability of equipment and processes so as to function properly.

CHAPTER FIVE
PROPOSED FRAMEWORK

This chapter includes the proposed framework that is going to be suggested for the case company. The researcher has been conducted the relationship between the selected CSF and maintenance performance. Concerning the relationship it was conducted that correlation analysis and regression analysis between those independent variables (organizational factors, human factors, technological factors and resource factors) and dependent variables (maintenance performance). Based on the result found from the analysis all the independent variables has a positive and significant impact on the maintenance performance of the company where as one of the independent variable, human factors has the dominant factors with high significant in affecting the maintenance performance of the company from the other factors (independent variables). According to the result finding this indicates that all the independent variables are the critical areas that lead in enhancing of the maintenance performance.

Considering the result finding that all the selected CSF (independent variables) has a positive significant in affecting maintenance performance, this indicates that the critical areas has to be addressed to enhance the company maintenance performance. To do so relationship between CSF and TPM pillars has been conducted by considering compatibility of TPM pillars with respect to each CSF. Based on this the framework contains all the significant critical factors and the selected pillars that are going to be practiced to address those critical areas.

The proposed TPM framework presented in the figure5.1 below:

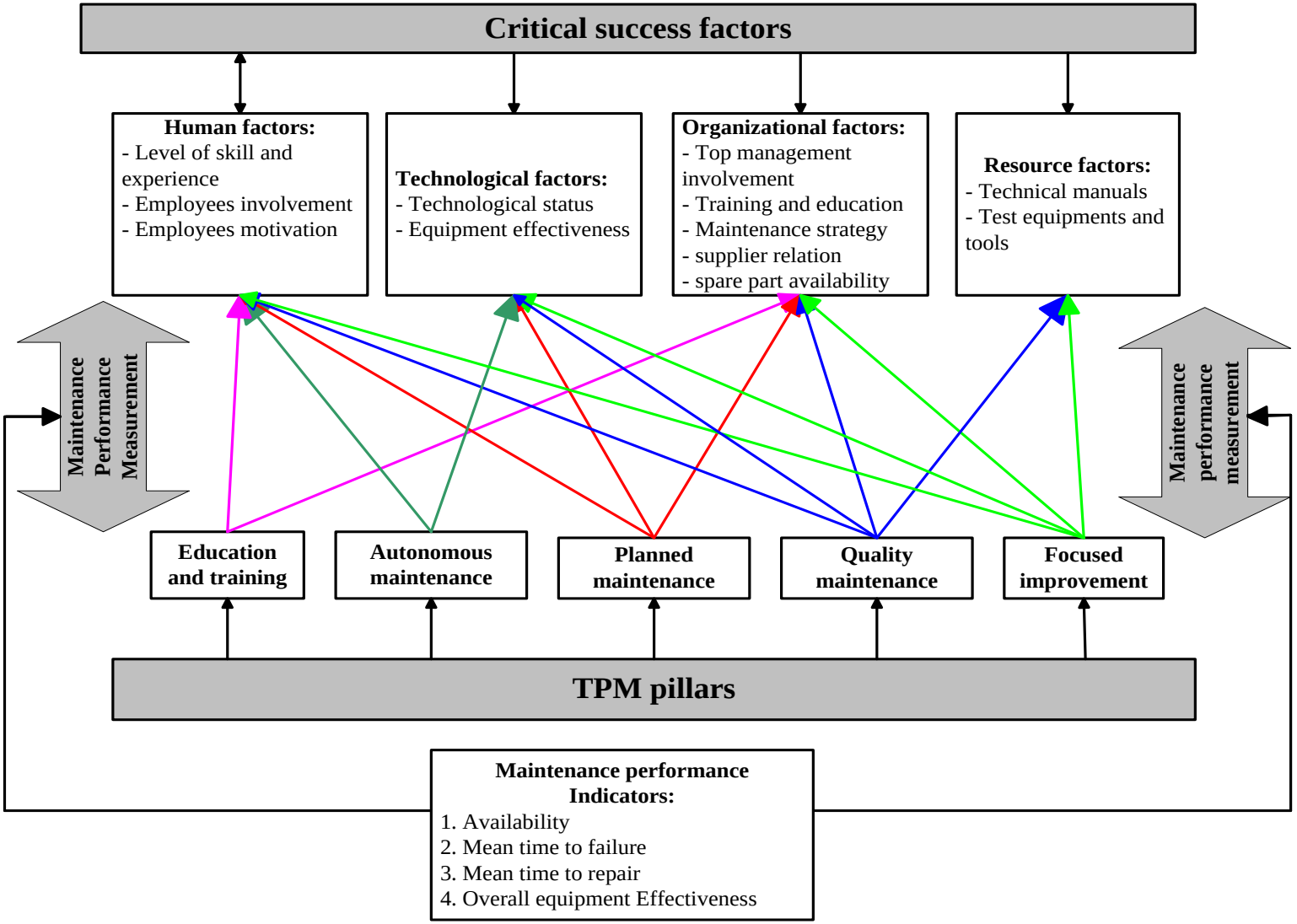


Figure 5.1: proposed TPM implementation Framework

5.1. Framework Description

In the above figure5.1 TPM framework has proposed for the case company. The framework developed based on the selected TPM pillars for each CSF, Here are presented that the action plans with respect to each pillars.

Pillar: Education and Training

This pillar is one of the TPM activities that have to be practiced in continuous basis. About the significant factor that has high contribution in the maintenance performance of the company; human factor is the dominated factors from all other CSF. This means human factors should get a better attention to enhance the company maintenance performance.

Concerning the significant critical factors, relationship has done between those significant factors and TPM pillars and the researcher has selected the compatible TPM pillars to address the critical factors of the company due to the reason that increased skills and performance of all personnel throughout the company is essential for the successful implementation of TPM because it has the ability to maximize the potentials of employees.

To this end the actions that have to be done while practicing Education and training pillars presented in the figure5.2 below:

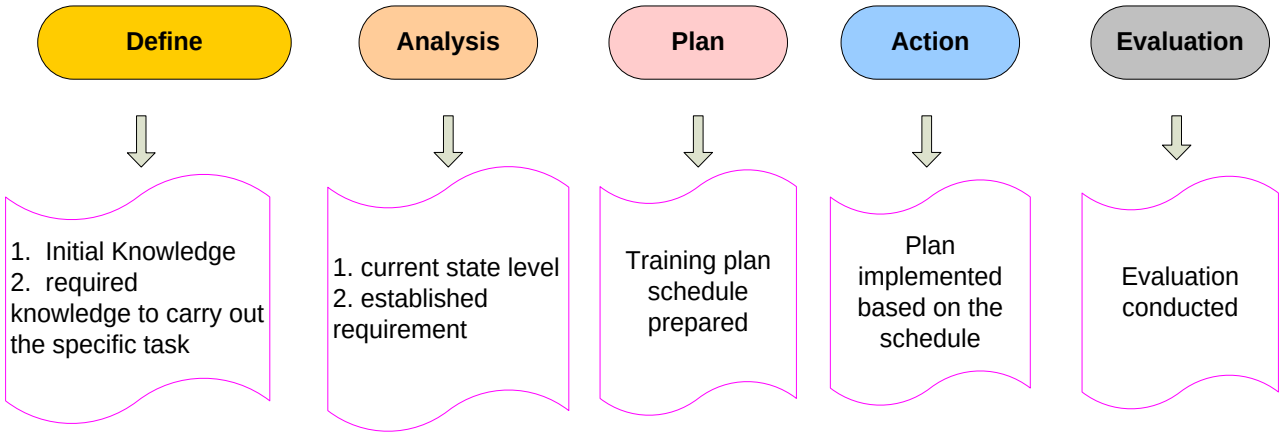


Figure 5.2: Action plan for Education and training pillar

Pillar: Autonomous Maintenance

As per the finding found in this study that human factor is the dominated factors that has a high significant contribution in affecting maintenance performance of the company this indicated that increasing the involvement employees will lead in enhancing maintenance performance. For this matter maximize employee engagement and capability levels and get measurable improvement through practicing Autonomous maintenance is one approach. Practicing of Autonomous Maintenance will improve Overall Equipment Effectiveness (OEE) by reducing performance loss and increasing equipment availability.

Accordingly here in the figure5.3 below the actions that is going to be exercised presented.

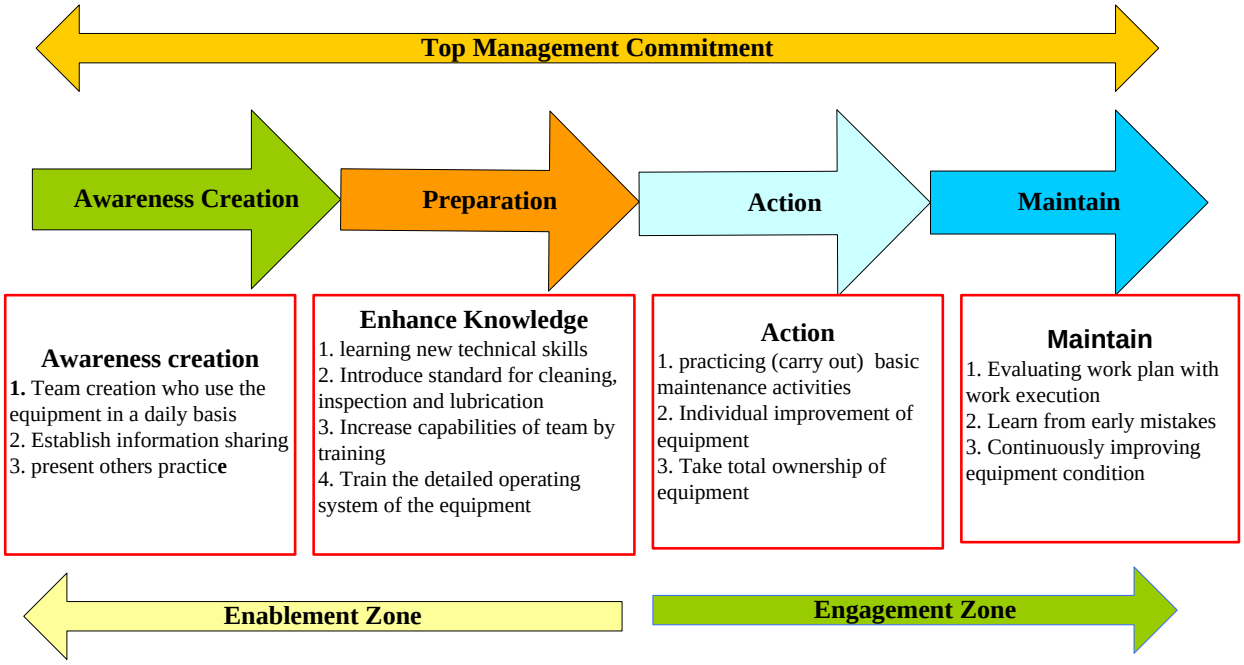


Figure 5.3: Action plan for Autonomous maintenance practice

Pillar: planned maintenance

As per the finding obtained in this study the researcher has done relationship between the critical success factors that have a positive significant contribution in enhancing maintenance performance and TPM pillars, based on that Planned maintenance is one of the pillars that are going to be practiced in the Implementation of TPM to address the technological and organizational factor of the company. The benefits obtained from this pillar are reduction in breakdowns, which leads to reduced cost and improved machine efficiency. The pillar will also contribute to improved quality and safety performance.

To do so here in the figure5.4 below the actions that is going to be exercised presented.

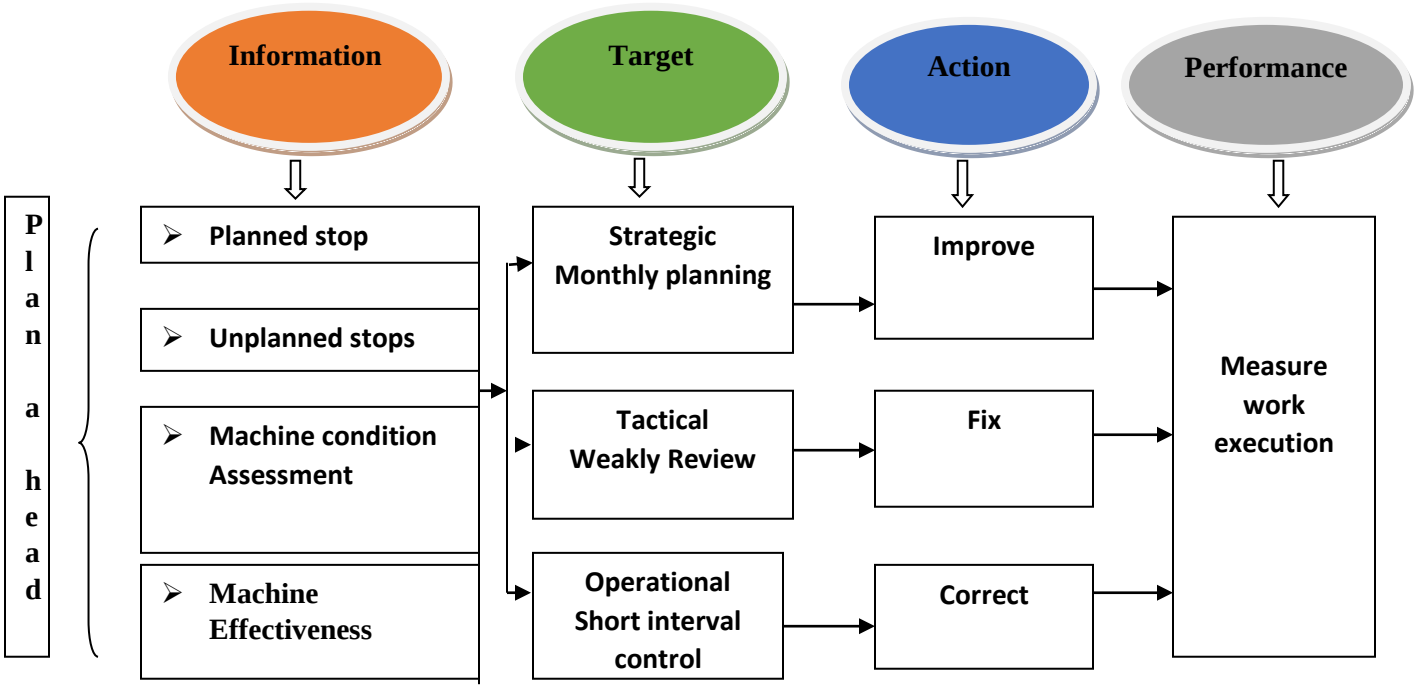


Figure 5.4: Action plan for practicing planned maintenance pillar

Pillar: Quality maintenance

Quality maintenance is used in any of the process to eliminate non-conformances in an organized manner. From the finding found in this research the critical areas are selected out according to that the critical factors has a significant impact in affecting maintenance performance of the company. In relation to the critical factor which is organizational factors, quality maintenance is the selected pillar to practice TPM and enhance the maintenance performance of the company by addressing the organizational factors. This is due to the reason that quality maintenance helps to understand and control the process interactions between manpower, material, machines and methods.

Accordingly to address this critical factor the following action plan is presented in the figure5.5 below:

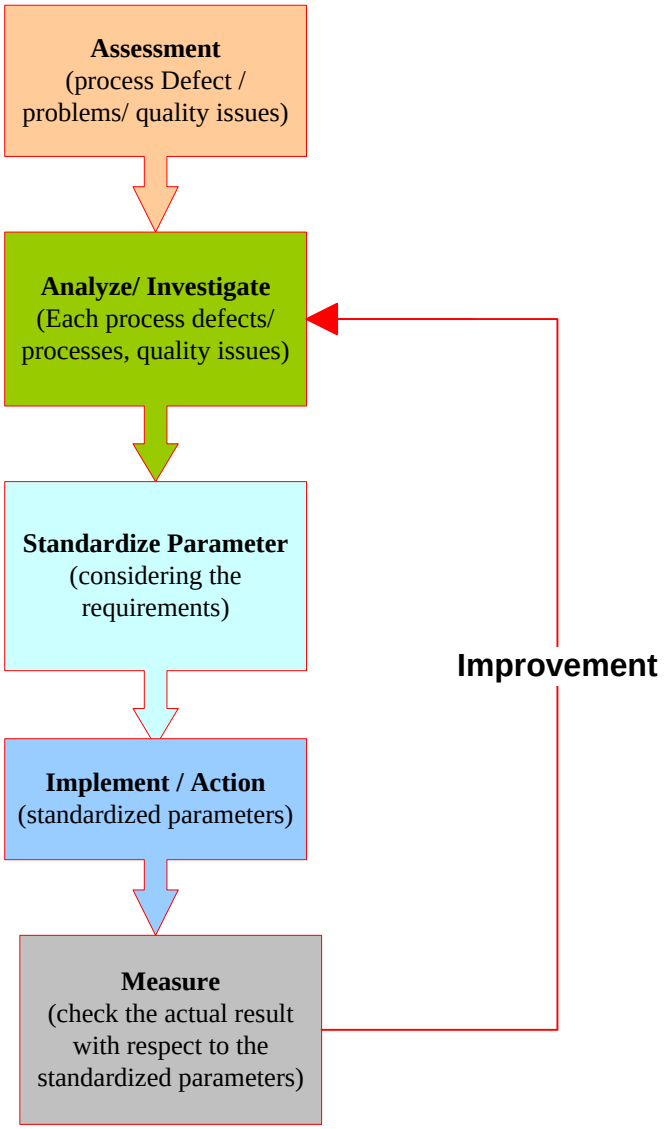


Figure 5.5: Action plan for practicing Quality maintenance pillar

Pillar: Focused Improvement

The researcher conducted the relationship between the critical success factors and maintenance performance of the company, as per the result found from the finding organizational factor has a positive significant impact in affecting maintenance performance of the company and to address this critical issue and enhance the company maintenance performance, practicing TPM through exercising pillars is an effective way. Accordingly focused improvement is one of the TPM pillars that eliminate identified specific losses in any process.

In the figure5.6 below action plan to address the critical factor of the company presented:

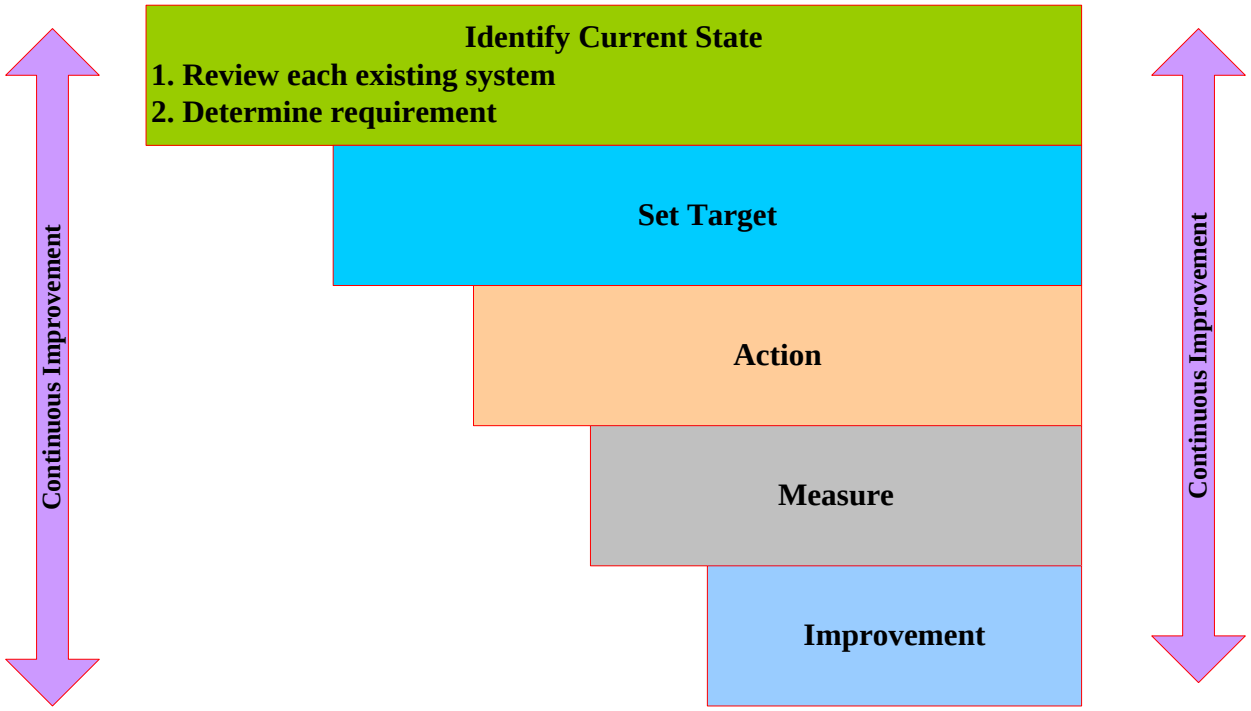


Figure 5.6: Action plan for focused improvement pillar

General Implementation procedures

Generally to practice TPM activities, the first activity before proceeding to the implementation process is creating of awareness and this has to be sustained until desired outcome found. As (Ramachandra et al., 2016) mentioned the key factors for TPM implementation are workers involvement and top management support. Accordingly top management commitment is the basics supports to follow up each activity are exercised as planned in a continuous manner. The other requirements for practicing, strong skill development for each and every individual through training and education should be provided along with the process.

Accordingly the general TPM implementation procedure before practicing the pillars presented in the figure5.7 below:

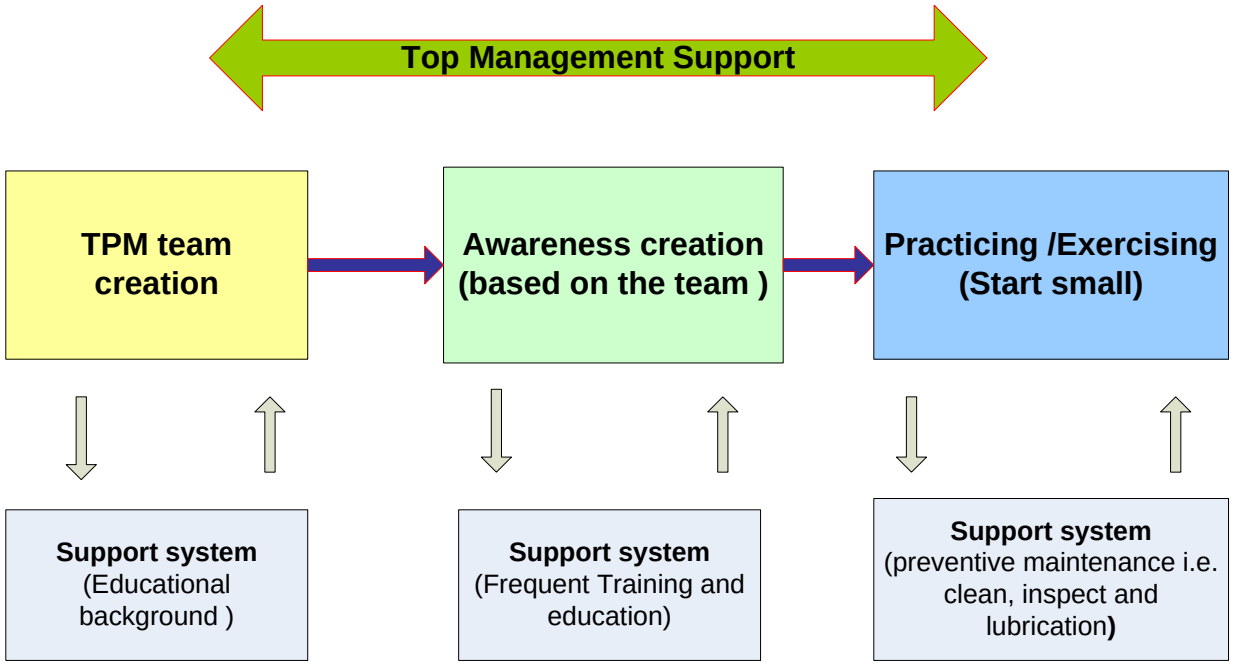


Figure 5.7: General TPM Implementation Procedures

5.2. Validation of the proposed Framework

The researcher has presented proposed TPM framework considering the selected CSF that has a positive significant impact in affecting the maintenance performance of the company and pillars of TPM. Accordingly to make judgments about the soundness of the proposed framework whether it can fit the company and achieve the desired outcome.

To do this the researcher had chosen expertise opinions to validate the proposed framework. Accordingly three steps has been followed for validation process

Step 1: Selecting Expertise

In this regards selecting the appropriate expertise for judgment is the critical thing to get a good feedback for this matter, a person who have a well strong knowledge and expert in this area is recommended:

The selected expertises for proposed framework validation are:

- Managing Director of Savvy PLC.
- Maintenance manager of Benchmark Engineering PLC
- Maintenance Department Manager of Artistic Printing

The above selected expertises are selected due to the reason that they have a direct relation in printing technology and maintenance service. The first two expertise are a private companies engaged in providing printing machineries, spare parts and maintenance service for enterprises that are engaged in printing sectors.

The other expertise was maintenance manager of Artistic printing. Artistic printing is a governmental printing enterprise that provides printing goods. The company also engaged in giving printing technology training.

Step 2: preparing interview question

Here in this step the researcher has prepared questions for conducting the interview with the expertise regarding the soundness of the proposed framework.

The questions are:

1. Do you think that the proposed framework can improve the maintenance performance of the company?
2. What should be included to address the company maintenance performance issues beside than those included in the proposed framework?

Step 3: Conduct Interview

As per the selected expertise, the researcher has conducted interview with the expertise regarding the proposed framework. The finding found from the expertise interview was that the proposed framework can improve the maintenance performance of the company and relevant for the sector but they strongly mentioned that awareness creation for all employees in the company in a frequent basis has to be lined up with the proposed model that since most of the peoples engaged in printing sectors knowledge level is different some have well skilled and awareness some are not. Considering their opinions, the researcher has done some modification to the general TPM implementation procedures.

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

6.1. Conclusion

This study has conducted considering different critical success factors of TPM with respect to maintenance performance. As per the analysis the result obtained indicates that the critical success factors such as organizational factors, human factors, technological factors and resource factors has a significant impact in affecting maintenance performance of the company. The highest contributor in affecting the maintenance performance of the company from all the critical success factors, human factors has the dominant. In regarding to determine the current situation of the effectiveness of production system, effectiveness of the maintenance system and performance of the machines, downtime analyzed and OEE calculated, from this the result obtained reveals that the occurrence of downtime in the company is high which disrupt the planned production schedules and regarding to the OEE values of machines, it was very low. In this regard as per the finding from the survey with respect to maintenance strategy used in the company, involvement of all the staffs from top management to work floor workers in improving the maintenance performance, training and education given to the maintenance and production operators, skill and experience level of the technicians in the company has also a high significant impact in affecting the maintenance performance. Accordingly all the sub-factors that are selected under each critical factor also have a positive significant impact in affecting the company maintenance performance. This means giving attention to those critical success factors that has a positive significant impact will leads in improving of the desired maintenance performance. Accordingly the researcher has done a relationship between the CSF and Pillars of TPM that to address each critical factor with TPM pillars. Along with this TPM framework proposed and validated through expertise opinions that has a well experience in this area to guarantee its effectiveness.

6.2. Recommendation

Based on the finding obtained, the recommendation presented as follows

- Training and education is the basic knowledge enhancing tools, it's recommended that the company has to develop training and education system that can improve skills of operators and maintenance technicians in a frequent basis.
- The company has to start evaluating the skills and knowledge of maintenance technicians with respect to their contribution in performing maintenance activities.
- It's recommended that the company top management has to work with all the shop floor workers and maintenance technicians to improve the maintenance performance of the company.
- With respect to the involvement of production operators in performing maintenance activities, there has to be an awareness creation along with training education to bring their motivation in handling the machines that they are operated.
- It's recommended that determining the machine performance or efficiency with different tools and techniques such as OEE in a frequent basis has to be practiced in the company to achieve equipment effectiveness.

6.3. Future Research work

- Practicing TPM in our country Ethiopia has not seen in any of local manufacturing industries unless the international companies such as Heniken, accordingly as future research work TPM implementation is the research area that should be considered in the future.
- Rather than the four critical success factors considered in this research such as organizational factors, human factors, technological factors and resource factors with respect to maintenance performance, considering the critical factors work culture impact in maintenance performance is the research area that should be considered in the future.

REFERENCE

Abhishek Jain, H. S. and R. S. B. (2018). Identification of key enablers for Total Productive Maintenance (TPM) implementation in Indian SMEs: a graph theoretic approach. *An International Journal*.

Adesta, E. Y. T., Prabowo, H. A., & Agusman, D. (2018). Evaluating 8 pillars of Total Productive Maintenance (TPM) implementation and their contribution to manufacturing performance. *IOP Conference Series: Materials Science and Engineering*, *290*(1). https://doi.org/10.1088/1757-899X/290/1/012024

Ahuja, I. P. S., and Kumar, P. (2009). A Case Study of Total Productive Maintenance Implementation at Precision Tube Mills. Engineering. *Journal of Quality in Maintenance*, *15*(3), 241–258.

Ahuja, I.P.S. and Khamba, J. S. (2008). Strategies and success factors for overcoming challenges in TPM implementation in Indian manufacturing industry. *Journal of Quality in Maintenance Engineering*, *14*(2), 123–147.

Ahuja, IPS, & Khamba, J. (2007). An evaluation of TPM implementation initiatives in an Indian manufacturing enterprise. *Journal of Quality in Maintenance Engineering*, *13*(4), 338–352.

Aziz, I., Karim, S., & Hossain, M. (2013). Effective Implementation of Total Productive Maintenance and Impacts on Breakdown Time and Repair & Maintenance – A Case Study Of A Printing Industry In Bangladesh. *International Journal of Engineering Research and Development*, *8*(1), 1–9.

Bakri, A. H., Rahim, A. R. A., Yusof, N. M., & Ahmad, R. (2012). Boosting Lean Production via TPM. *Procedia - Social and Behavioral Sciences*, *65*, 485–491. https://doi.org/10.1016/j.sbspro.2012.11.153

Baluch N, A. C. S. B. and M. S. B. (2010). Maintenance Management Performance – An Overview towards Evaluating Malaysian Palm Oil Mill. *The Asian Journal of Technology Management*, *3*(1), 1–5.

Bartz, T., Siluk, J. C. M., & Bartz, A. P. B. (2014). Improvement of industrial performance with TPM implementation. *Journal of Quality in Maintenance Engineering*, *20*(1), 2–19. https://doi.org/10.1108/JQME-07-2012-0025

Bhoyar, A. S., Raut, L. P., & Mane, S. (2017). Total Productive Maintenance : The Evolution in Maintenance and Efficiency Total Productive Maintenance : The Evolution in Maintenance and Efficiency. *International Journal of Engineering Research and Application*, *7*(11), 26–32. https://doi.org/10.9790/9622-0711012632

Chandrahas, S. K. M. and D. M. (2015). MAINTENANCE STRATEGY AND DECISION MAKING – AHP METHOD. *International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974*, 256–258.

Chandran, S. (2015). TPM Implementation Approach. *Journal of Industrial Engineering and Management*, (June).

Csaba Horvath. (2010). Integrated maintenance management model in the printing industry. *Journal of Graphic Engineering and Design*, *1*, 16–22.

Deshpande, VS, & Modak, J. (2002). Application of RCM to a medium scale industry. *Reliability Engineering & System Safety*, *77*(1), 31–43.

Desta, T., Yimer, W., Ramulu, P. J., Murthy, N., & Anbusagar, N. R. R. (2015). Prospects of Maintenance Management Functions in Sugar Industries: A Case Study on Ethiopian Metehara Sugar Factory. *7th International Conference on Latest Trends in Engineering & Technology*, 26–27. https://doi.org/10.15242/iie.e1115050

Díaz-Reza, J., García-Alcaraz, J., Avelar-Sosa, L., Mendoza-Fong, J., Sáenz Diez-Muro, J., & Blanco-Fernández, J. (2018). The Role of Managerial Commitment and TPM Implementation Strategies in Productivity Benefits. *Applied Sciences*, *8*(7), 1153. https://doi.org/10.3390/app8071153

Dutta, S., & Dutta, A. K. (2016). A Review on the experimental study of Overall Equipment Effectiveness of various machines and its improvement strategies through TPM implementation. *International Journal of Engineering Trends and Technology*, *36*(5), 224–232. https://doi.org/10.14445/22315381/ijett-v36p242

Dwight, R. (1999). Searching for real maintenance performance measures. *Journal of Quality in Maintenance Engineering*, *5*(3), 258–275.

Eti, M. C., & Ogaji, S.O.T.Robert, S. D. (2004). Implementing total productive maintenance in Nigerian manufacturing industries. *Applied Energy*, *79*, 385–401.

Eyoh, J. and Kalawsky, R. S. (2018). *strategies in oil and gas achievements and future Evolution of Maintenance Strategies in oil and Gas Industries : The Present Achievements and Future Trends* .

Fredrikssom, G. and H. L. (2012). *An analysis of maintenance strategies and development of a model for strategy formulation – A case study An analysis of maintenance strategies and development of a model for strategy formulation Department of Product and Production Development*. CHALMERS UNIVERSITY OF TECHNOLOGY.

Garg, Amik, & Deshmukh, S. (2006). Maintenance management: literature review and directions. *Journal of Quality in Maintenance Engineering*, *12*(3), 205–238.

Gupta, P., Vardhan, S., & Al Haque, M. S. (2015). Study of success factors of TPM implementation in Indian industry towards operational excellence: An overview. *IEOM 2015 - 5th International Conference on Industrial Engineering and Operations Management, Proceeding*. https://doi.org/10.1109/IEOM.2015.7093740

H/Mariam, H. (2018). *Productivity Improvement through the integration of lean and work study*.

(June).

Hanssen, R. (2002). Overall equipment effectiveness: A powerful production/maintenance tool for increased profits. *Industrial Press Inc,Newyork.*

Herry, A. P., Farida, F., & Lutfia, N. I. (2018). Performance analysis of TPM implementation through Overall Equipment Effectiveness (OEE) and Six Big Losses. *IOP Conference Series: Materials Science and Engineering*, *453*(1). https://doi.org/10.1088/1757-899X/453/1/012061

Hj. Bakri, A., Abdul Rahim, A. R., Noordin, M. Y., Mohd Razali, W. K., Mohd Zul-Waqar, M. T., & Shaiful Anwar, I. (2014). A Review on the Total Productive Maintenance (TPM) Conceptual Framework. *Applied Mechanics and Materials*, *660*(January 2017), 1043–1051. https://doi.org/10.4028/www.scientific.net/amm.660.1043

Kaur, Mandeep, Singh, Kanwarpreet, & Singh Ahuja, I. (2012). An evaluation of the synergic implementation of TQM and TPM paradigms on business performance. *International Journal of Productivity and Performance Management*, *62*(1), 66–84.

Kedar, A. P., & Borikar, V. N. (2016). Critical Success Factors for Effective Implementation of TQM & TPM. *International Journal for Innovative Research in Secience & Technology*, *2*(09), 160–164.

Kumar, Jitendra, Kumar Soni, Vimlesh, & Agnihotri, G. (2014). Impact of TPM implementation on Indian manufacturing industry. *International Journal of Productivity and Performance Management*, *63*(1), 44–56.

Kumar Aroor, K., Nayak, M., & Krishna, E. (2015). Study of Total Productive Maintenance and Manufacturing Performance of a Manufacturing Industry. *Journal of Business and Management (IOSR-JBM)*, *17*(9), 106–120. https://doi.org/10.9790/487X-1791106120

Kumar, S., Bhushan, R., Swaroop, S., Tech, M., Engineering, I., & Ism, I. I. T. (2017). Study of total productive maintenance & it ' s implementation approach in steel manufacturing industry : A case study of equipment wise breakdown analysis. *International Research Journal of Engineering Technology*, *4*(8), 608–613.

Kumar Sharma, R., & Gopal Sharma, R. (2014). Integrating six sigma culture and TPM framework to improve manufacturing performance in SMEs. *Quality and Reliability Engineering International*, *30*(5), 745–765. https://doi.org/10.1002/qre.1525

Lazim, H. M., Salleh, M. N., Subramaniam, C., & Othman, S. N. (2013). Total Productive Maintenance and Manufacturing Performance: Doeas Technical Complexity in the Production Process Matter? *International Journal of Trade, Economics and Finance*, 380–383. https://doi.org/10.7763/ijtef.2013.v4.321

Lemma, E., Singh, A. P., & Dayal, B. (2013). TPM-The Need of the Hour for the Ethiopian Textile Industry. *Ethiopia Journal Science and Technology*, *6*(2), 103–126.

Maletic, D., Maletic, M., A.-N. and B. G. (2014). The role of maintenance in improving company ' s competitiveness and profitability : a case study in a textile company. *Journal of Manufacturing Technology Management*, *25*(4), 441–456.

Martomo, Z. I., & Laksono, P. W. (2018). Analysis of total productive maintenance (TPM) implementation using overall equipment effectiveness (OEE) and six big losses: A case study. *AIP Conference Proceedings*, *1931*. https://doi.org/10.1063/1.5024085

mckone, k.e, schneder,R.G,Cua, K. . (1999). Total Productive maintenance: A contextual view. *Journal of Operations Management*, *17*, 123–144.

Mekasha, E. (2018). *Thesis Draft Maintenance Management Framework Development for Competitiveness of Food and Beverage Industry : A Case Study on Asku PLC*. Addis Ababa Technology Institutes.

Melesse Workneh Wakjira, S. and A. P. (2012). Total Productive Maintenance: A Case Study in Manufacturing Industry By. *Global Journal of Research in Engineering*, *12*(1).

Mentesinot, M. (2017). *Enhancing Productivity through Improved Maintenance System (Case Study in Dashen Brewery Share Company).* Addis Ababa Institutes of Technology.

Meseret. (2007). *No T*. Addis Ababa University.

Mey, J. H. P. M. (2011). *The Impact of Implementing World Class Manufacturing on Company Performance : A Case Study of the ArcelorMittal South Africa Saldanha Works Business Unit*. University of Stellenbosch.

Miroslav FUSKO, I. S. and M. R. (2016). *New trends for maintenance management*. (March).

Mwanza, B. G., & Mbohwa, C. (2015). Design of a Total Productive Maintenance Model for Effective Implementation: Case Study of a Chemical Manufacturing Company. *Procedia Manufacturing*, *4*(Iess), 461–470. https://doi.org/10.1016/j.promfg.2015.11.063

Nakajima, S. (1984). Introduction to TPM: Total productive maintenance. In *Productivity Press*. Cambridge.

Nallusamy, S., & Majumdar, G. (2017). Enhancement of overall equipment effectiveness using total productive maintenance in a manufacturing industry. *International Journal of Performability Engineering*, *13*(2), 1–16.

NASA. (2008). *Rcm*. Retrieved from http://www.hq.nasa.gov/office/codej/codejx/Assets/Docs/NASARCMGuide.pdf

Ng, K. C., Chong, K. E., & Goh, G. G. (2013). Total productive maintenance strategy in a semiconductor manufacturer. *IEEE International Conference on Industrial Engineering and Engineering Management.*

Okpala, C. C., Anozie, S. C., & Ezeanyim, O. C. (2018). The Application of Tools and

Techniques of Total Productive Maintenance in Manufacturing. *International Journal of Semantic Computing*, *8*(6), 18115–18121.

Oleghe, O., & Salonitis, K. (2019). The application of a hybrid simulation modelling framework as a decision-making tool for TPM improvement. *Journal of Quality in Maintenance Engineering*. https://doi.org/10.1108/JQME-06-2018-0056

Parida, Aditya, & Chattopadhyay, G. (2007). Development of a multi-criteria hierarchical framework for maintenance performance measurement (MPM). *Journal of Quality in Maintenance Engineering*, *13*(3), 241–258.

Parida, Aditya, Kumar, Uday, Galar, Diego, Stenström, C. (2015). Performance measurement and management for maintenance: a literature review. *Journal of Quality in Maintenance Engineering*, *21*(1), 2–33.

Pascal, V., Toufik, A., Manuel, A., Florent, D., & Frédéric, K. (2019). Improvement indicators for Total Productive Maintenance policy. *Control Engineering Practice*, *82*(October 2018), 86–96. https://doi.org/10.1016/j.conengprac.2018.09.019

Patidar, L., Soni, V. K., & Soni, P. (2017). Maintenance Strategies and their Combine Impact on Manufacturing Performance. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, *7*(1), 13–22.

Patil, B. B., Badiger, A. S., & Mishrikoti, A. H. (2018a). A Study on Productivity Improvement through Application of Total Productive Maintenance in Indian Industries-A Literature Review. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN*, *15*(3), 13–23. https://doi.org/10.9790/1684-1503041323

Patil, B. B., Badiger, A. S., & Mishrikoti, A. H. (2018b). *A Study on Productivity Improvement through Application of Total Productive Maintenance in Indian Industries - A Literature Review*. *15*(3), 13–23. https://doi.org/10.9790/1684-1503041323

Piechnicki, A.S.; Herrero Sola, A.V.; Trojan, F. (2015). Decision-making towards achieving world-class total productive maintenance. *Int. J. Oper. Prod. Manag.*, *35*, 1594–1621.

Pintelon, L.M. and Parodi-Herz, A. (2008). *Maintenance: an evolutionary perspective Complex System Maintenance Handbook, (Series in Reliability Engineering), Springer-Verlag,*. London.

Prashanth Pai, M., Ramachandra, C. G., Srinivas, T. R., & Raghavendra, M. J. (2018). A Study on Usage of Total Productive Maintenance (TPM) in Selected SMEs. *IOP Conference Series: Materials Science and Engineering*, *376*(1). https://doi.org/10.1088/1757-899X/376/1/012117

prEN 13306. (1998). *Draft European Standard – Maintenance Terminology.* Brussels.

R. Peach, H. E. & J. K. V. (2016). A MAINTENANCE PERFORMANCE MEASUREMENT FRAMEWORK THAT INCLUDES MAINTENANCE HUMAN FACTORS: A CASE

STUDY FROM THE ELECTRICITY TRANSMISSION INDUSTRY R. Peach 1 , H. Ellis 1 & J.K. Visser 1 * ARTICLE INFO. *South African Journal of Industrial Engineering*, *27*(August), 177–189.

R.S. Velmurugan and Tarun Dhingra. (2015). Maintenance Strategy Selection and its Impact on Maintenance Function - A International Journal of Operations & Production Management Article information : *International Journal of Operation and Production Management*, *35*(12), 1622–3577. https://doi.org/10.1108/IJOPM-01-2014-0028

Rajdeep Singh, H. K. (2017). Role of TPM Paradigms in Achieving Manufacturing Excellence in Industry. *International Journal of Innovative Research in Science, Engineering and Technology*, *6*(8), 10. https://doi.org/10.15680/IJIRSET.2016.0608116

Ramachandra, C., Prashanth Pai, M., Srinivas, T., & Raghavendra, M. (2016). OEE - A Tool to Measure the Effectiveness of TPM Implementation in Industries - A Review. *Global Research and Development Journal for Engineering*, *1*(12), 92–96.

S. N. Seleem, E.-A. A. and A. E.-A. (2018). IDENTIFICATION OF CRITICAL SUCCESS FACTORS FOR TOTAL PRODUCTIVE MAINTENANCE. *18th International Conference on Applied Mechanics and Mechanical Engineering*, 115–156. https://doi.org/10.1007/978-3-8350-9333-1_5

Shaaban, M. S., & Awni, A. H. (2014). Critical success factors for total productive manufacturing (TPM) deployment at Egyptian FMCG companies. *Journal of Manufacturing Technology Management*, *25*(3), 393–414. https://doi.org/10.1108/JMTM-09-2012-0088

Shahin, A. (2014). *A Comprehensive Approach for Maintenance Performance Measurement Arash Shahin*. (March).

Shanmugam, A. and Paul Robert, T. (2015). Human factors engineering in aircraft maintenance: a review. *Journal of Quality in Maintenance Engineering*, *21*(4), 478–505.

Sharma, Anil, Yadava, GS, & Deshmukh, S. (2011). A literature review and future perspectives on maintenance optimization. *Journal of Quality in Maintenance Engineering*, *17*(1), 5–25.

Sharma, A. K., Shudhanshu, & Bhaerdwaj, A. (2012). Manufacturing Performance and Evolution of Tpm. *International Journal of Engineering Science and Technology*, *4*(03), 854–866.

Sivaram, N. M., Devadasan, S. R., Murugesh, R., Karthi, S., & Sreenivasa, C. G. (2014). Synergising total productive maintenance elements with ISO 9001:2008 standard based quality management system. *TQM Journal*, *26*(6), 534–549. https://doi.org/10.1108/TQM-08-2012-0059

Starr, A., Al-najjar, B., Holmberg, K., Jantunen, E., Bellew, J., & Albarbar, A. (2010). *Maintenance Today and Future Trends*.

Strategosin. (2017). The tools of Total Productive Maintenance.

Sugumaran, C., Muthu, S., Devadasan, S. R., Srinivasan, K., Sivaram, N. M., & Rupavathi, N. (2014). Integration of QFD and AHP with TPM: an implementation study in an automotive accessories manufacturing company. *International Journal of Productivity and Quality Management*, *14*(3), 263. https://doi.org/10.1504/ijpqm.2014.064806

Syum. (2010). *performance evaluation of selected Ethiopian commercial banks using balanced score card*.

Technology Promotion Association. (2002). Total Productive Management (TPM). Retrieved January 24, 2011, from http://www.tpa.or.th/shindan/detail.php?page=tpm

Tsarouhas, P. (2013). Evaluation of overall equipment effectiveness in the beverage industry. *International Journal of Production Research*, *51*(2), 515–523.

Venkateswaran, N. (2017). Arabian Journal of Business and Total Productive Maintenance (TPM) Practices Adopted at Manufacturing Unit : An Analysis. *Arabian Journal of Business and Management Review*, *7*(4). https://doi.org/10.4172/2223-5833.1000313

Virupakshar, A. B., & Badiger, A. (2016). *ENHANCING PRODUCTIVITY THROUGH TPM CONCEPTS : A CASE STUDY*. (2), 23–26.

Willmott, P. (1994). Total quality with teeth. *The TQM Magazine*, *6*(4), 48–50.

APPENDIX-A

OEE of machines in offset printing section

	OEE								
	M-Offset	Speed Master102/1	GTO-15	Speed Master74/2	Sakurai-Awarie	Sakurai 266-1	GTO-46	New M-Offset-031	GTO-New
Hamle	34.5	31.4	67.4	35.5	16.7	41.3	68.2	28.5	32
Nehase	35.2	19.5	63.9	46.2	6.7	37.3	61.8	39.7	78.2
Meskerem	41	21.6	51.1	45	20.8	29.2	75.8	69.5	74.3
Tikimit	38.2	0.14	57.7	34	1.2	23.4	56.7	37	29.3
Hidar	23	16.8	67.5	29.8		39.6	73.6	30.8	59
Tahisas	15.7	36	52	22.7		33.2	70	52.7	64
Tir	19.8		78.3	52.5	1.1	24.6	42.6	46.3	79
Yekatit	38.8		48.6	39.3	26.9	23.4	50.7	26	45
Megabit	22.5		60.8	32	51.8	26	50	14	61.2
Miyazia	0.7	12.2	69.5	32.4	53.6	29.2	66	41	20
Ginbot	31.3	7.4	73.5	37.8	3.1	35.3	41	52.9	54.5
Sene	25	22.8	43.2	50.1	14.8	33.9	54.7	44.2	51.7

OEE of machines in Wave offset printing section

	OEE			
	Solna 1	Solna 2	Wive546	Wive578
Hamle			11	8
Nehase			5	12.8
Meskerem	8.3	15.7	10.9	10.6
Tikimit	15	3.6	42.3	6
Hidar	4.4	0.9	6.8	17.1
Tahisas	10.2	1.6	7	3.4
Tir	3	2.3		2.7
Yekatit	16.7	13.5	0.5	
Megabit	53	17.3	2	6.1
Miyazia	58.4	35	7.3	20.6
Ginbot	13.6	11	8.4	11
Sene	11.3	6.7	18.5	10.5

OEE of machines in Letterpress printing section

	OEE						
	GTO2-026	GTO1-027	GTO3-028	platin-22	Cylinder-09	platin-024	Cylinder-30
Hamle	59.2	5.4		47.6	61.8	62	61.7
Nehase	55	0.1	0.1	57.7	60.7	64.4	58
Meskerem	36.7	0.7	3.5	71.8	63	81	64.6
Tikimit	74.4	0.2	0.04	61.6	61.6	75.7	55.2
Hidar	21			65	57.3	61.2	48.8
Tahisas	34.6			75.5	54.5	61.1	48.6
Tir	30.8	2.2		68.7	56.2	62.8	42.8
Yekatit	7			85.1	55.7	75.3	59
Megabit	9.8			80.4	76.1	76.5	71.5
Miyazia	69.3	17.7	19	83.7	79.1	77	73.5
Ginbot	68			70.9	46	78	58.5
Sene	41.1	0.9		80.3	75.7	77	75.3

OEE of machines in Security printing section

	OEE													
	platin-02	Cylinder-08	platin-013	platin-014	Cylinder-15	Cylinder-16	platin-021	platin-026	Speed Master102/1	Roland-200	Sakuri 266/2	Cylinder-28	Roland-10	Sakuray2
Hamle	39.5	61.5	42.2	66.6	47.9	72.6	51	66.9	20.4		71.3	83.2	62.9	54.6
Nehase	57.8	77.3	73.3	87	80.1	55	62.6	85	18.4			86.4	50.5	36.6
Meskerem	31.2	59	73.4	31.9	58.6	49.2	63.2	40.9	14.1		40	89.2	21.8	51.4
Tikimit	59.9	79	90.9	58.3	64.4	81.2	78.7	67.7			39.2	87.1		28.7
Hidar	63.6	65	78.1	47.2	45.7	73.8	83.5	75.6	47.4		90.2	75.8		26
Tahisas	59.7	70.6	79.7	73.9	75	70	87.2	77.1	19		51	80.6		57.5
Tir	58.6	69.3	64.2	51.7	57.5	73.4	78.3	77.4	63.2	85	38	85.7		41.1
Yekatit	43.8	60.5	85.4	71.5	72.6	71.9	85.6	81.7		84	44.8	81.3		49
Megabit	32.4	48	76.4	27.3	62.3	19.2	83.1	82	84.8	55.9	79.2	74.7		35.4
Miyazia	64	53.9	83.3	62.7	3.3	36.9	80.9	88.9	17.9	81.1	53.1	69		26
Ginbot	51.6	70.7	82.4	48.2	57.5	78.9	75.6	76.1	11.8	69.1	58	63		40
Sene	78.5	54.4	82.6	79.3	61.8	70.3	87	74	17.2	65	45.9	39.6		50.2

APPENDEX-B

Addis Ababa University
Addis Ababa Institute of technology
School of Mechanical and industrial Engineering
Industrial Engineering Stream

Enhancing Maintenance Performance through TPM Concepts Questioner

Dear Participants;

I am Elisabet Nigussie conducting a thesis with title- ***"Enhancing maintenance performance through TPM Concept"*** for partial fulfillment of M.SC in industrial engineering at AAIT, AAU. With sincerity I would like to extend my deep appreciation to your company and respondents for the willingness and cooperation in undertaking this research. I request your kind cooperation in answering the questions as truthfully as possible. For other questions pertaining to this study, please contact Addis Ababa University, Addis Ababa Institute of Technology, School of Industrial and Mechanical Engineering. The information obtained from this questionnaire will be kept confidential and will not be used for any other purposes.

NB:

- ✓ Try to address the question that represent your "part" only
- ✓ For each questions in **part 2** table **"circle"** ◯ your response for each statement
- ✓ For the closed ended questions in **part 3** use **(√)** mark for your choice in the given box

Part 1: General information

1. Current Position: _____

2. Total year of experience: _____

3. How many years of working experience do you have? (At Berehanena selam)

A. Less than 5 years ☐ B, 5 – 10 years ☐ C. more than 10 years ☐

4. Educational background Level

A. 10+ 1 ☐ C. 10+3 ☐ E. Degree ☐ G. Others (Specify)……

B. 10+2 ☐ D. 10+4 ☐ F. Masters ☐

Part 2: Information on different factors

For the following questions **"circle"** (5) your response for each statement

Where, 5 = strongly agree, 4 = agree, 3 = unsure, 2 = disagree and 1= strongly disagree

3.1. For "Top management" only

No.	Items	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Information on Organizational Factors						
1.	You have good communication with the shop floor workers regarding maintenance activities and related issues?	1	2	3	4	5
2.	Are top management support maintenance technicians and Production operators to work together on maintenance issues?	1	2	3	4	5
3.	Your company gives training concerning new technologies frequently to maintenance technicians and operators?	1	2	3	4	5
4.	Is maintenance strategy (i.e. preventive maintenance, corrective maintenance, reactive maintenance & predictive maintenance) used in the company effective?	1	2	3	4	5
5.	Your company has strong and long term relation with suppliers (i.e. machine suppliers and spare part suppliers)?	1	2	3	4	5
6.	Your company selected equipment's supplier based on pre-determined criteria?	1	2	3	4	5

7.	You and your supplier share technical information with each other as necessary?	1	2	3	4	5
8.	Is there all the necessary spare parts are available in your company stock?	1	2	3	4	5
Information on Human Factors						
1.	Are maintenance technicians have strong skill and knowledge in performing maintenance activities?	1	2	3	4	5
2.	You think skills of maintenance technician's affect maintenance performance of your company?	1	2	3	4	5
3.	Are maintenance technicians are motivated in performing maintenance activities?	1	2	3	4	5
4.	Are production operators involve in performing maintenance activities i.e. cleaning, lubricating inspection and adjusting equipment's?	1	2	3	4	5
5.	Are Others departments integrate to work together with maintenance department?	1	2	3	4	5
Information on Technology Factors						
1.	Are the current technologies used in the company have an impact on the maintenance performance?	1	2	3	4	5
2.	Is the current equipment used for production effective?	1	2	3	4	5
Information on Resource Factors						
1.	Are technical manuals are available for all machines?	1	2	3	4	5
2.	Are necessary test equipment's and tools available for maintenance services?	1	2	3	4	5

3.2. For "Maintenance Team Leader" and "Engineering Expert" only

No.	Items	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Information on Organizational Factors						

1.	Is top management involve in achieving maintenance performance?	1	2	3	4	5
2.	Are the top management support maintenance technicians and Production operators to work together on maintenance related issues?	1	2	3	4	5
3.	You have good communication with the shop floor workers regarding maintenance activities and issues?	1	2	3	4	5
4.	Your company gives training to operators develop skills to routinely maintain equipment and identify emerging problems?	1	2	3	4	5
5.	Your company gives training concerning new technologies frequently to the maintenance technicians and operators?	1	2	3	4	5
6.	Are the maintenance strategy (i.e. preventive maintenance, corrective maintenance, reactive maintenance & predictive maintenance) uses in the company effective?	1	2	3	4	5
7.	Your company selected equipment's supplier based on pre-determined criteria?	1	2	3	4	5
8.	Your company has strong and long term relation with suppliers (i.e. machine, spare part, raw materials or other suppliers)?	1	2	3	4	5
9.	You and your supplier share technical information with each other?	1	2	3	4	5
10.	Is there all the necessary spare parts are available in your company stock?	1	2	3	4	5

Information on Human Factors

1.	Are maintenance technicians have skilled and have well knowledge in performing maintenance activities?	1	2	3	4	5
2.	You think skills of maintenance technician's affects maintenance performance of your company?	1	2	3	4	5
3.	Are production operators involve in performing maintenance activities i.e.	1	2	3	4	5

	cleaning, lubricating inspection and adjusting equipment's?					
4.	Are others departments integrate to work together with maintenance department?	1	2	3	4	5
5.	You think the maintenance technicians and production operators are motivated in performing maintenance activities?	1	2	3	4	5
Information on Technology Factors						
1.	Is current technology used in the company has an impact on the maintenance performance?	1	2	3	4	5
2.	Are the existing current equipment used for production effective?	1	2	3	4	5
Information on Resource Factors						
1.	Are the technical manuals are available for all machines?	1	2	3	4	5
2.	Are the maintenance technicians able to understand the technical manuals?	1	2	3	4	5
3.	Are the necessary test equipment's and tools available for maintenance services?	1	2	3	4	5

3.3. For "Maintenance Technician" & "Operator only

No.	Items	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Information on Organizational Factors						
1.	Are the top management support maintenance technicians and Production operators to work together on maintenance related issues?	1	2	3	4	5
2.	Is the top management have good communication with the shop floor workers regarding maintenance related issues?	1	2	3	4	5
3.	Your company gives training to develop	1	2	3	4	5

	skills to routinely maintain equipment and identify emerging problems?					
4.	Your company gives training concerning new printing machine technologies frequently?	1	2	3	4	5
5.	Is the maintenance strategy (i.e. preventive maintenance, corrective maintenance, reactive maintenance & predictive maintenance) use in the company effective?	1	2	3	4	5
6.	Is there all the necessary spare parts are available in your company stock?	1	2	3	4	5
	Information on Human Factors					
1.	You think you are skilled and have well knowledge in performing maintenance activities in your company?	1	2	3	4	5
2.	Are the production operators involve in performing maintenance activities i.e. cleaning, lubricating inspection and adjusting equipment's?	1	2	3	4	5
3.	Are others departments integrate to work together with maintenance department?	1	2	3	4	5
4.	You are motivated in performing maintenance activities and in solving any company problems?	1	2	3	4	5
5.	You think you are motivated in performing maintenance activities for the machine that you operate by yourself?	1	2	3	4	5
	Information on Technology Factors					
1.	Is the current technology used in the company has an impact on the maintenance performance?	1	2	3	4	5
2.	Are the existing current equipment used for production effective?	1	2	3	4	5
	Information on Resource Factors					

1.	Are the technical manuals are available for all machines?	1	2	3	4	5
2.	You have the ability to understand the technical manuals?	1	2	3	4	5
3.	Are the necessary test equipment's and tools available for maintenance services?	1	2	3	4	5
4.	You think unavailability of manuals affects in performing maintenance activities?	1	2	3	4	5
	Information on Maintenance performance					
1.	Are machines repetitively unavailable due to unplanned stoppage/failure?	1	2	3	4	5
2.	Is the level of machine downtime affect the planned production time?	1	2	3	4	5
3.	Is there a frequent unplanned machine failure in your company?	1	2	3	4	5
4.	Your company immediately repairs machines that failed due to unplanned stoppage and restore to the previous condition?	1	2	3	4	5
5.	Is the performance of machines in your company effective?	1	2	3	4	5
6.	Is the planned maintenance that is carried out effective?	1	2	3	4	5

Part 3: Information on Maintenance performance and TPM

1. What type of maintenance strategy does the company used?

Preventive ☐ predictive ☐

Corrective ☐ other (specify) _____

2. Level of company staff from top management to shop floor workers involvement in improving maintenance performance of the company?

High ☐ Medium ☐ Low ☐

3. Frequency of training and education given to the maintenance technicians and production operators?

Daily ☐ Monthly ☐ Quarterly ☐ Yearly ☐ Never ☐

4. Level of maintenance technician skill and experience in handling maintenance activities problems.

High ☐ Medium ☐ Low ☐

5. Level of production operator's involvement in performing maintenance activities and other company issues.

High ☐ Medium ☐ Low ☐ Never ☐