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Assessing Alignment of Maintenance Practices to Total Productive Maintenance Best Practice: A Case Study within a South African Conglomerate

Emmanuel Mabwe

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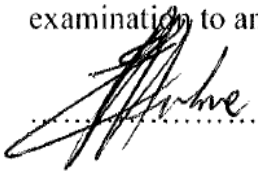
Supervisor: Ms Teresa Hatting

A Research Report Submitted to the Faculty of Engineering and the Built Environment, University of Witwatersrand, Johannesburg, in Partial Fulfilment of the Requirements for the Degree in Master of Science in Engineering

Johannesburg 2017

Declaration

I declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Science in Mechanical Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.



.....

(Signature of Candidate)

31st day of MARCH, 2017

March 2017

Abstract

In today's competitive world, a good maintenance approach is important for companies to remain competitive and control operational costs. There are various maintenance methods that can be applied in any organization, singly or combined, and such an approach must lead to increased availability, reliability and operability of equipment at an acceptable cost. World Class Manufacturing (WCM) has become a buzz phrase across the whole manufacturing world. Total Productive Maintenance (TPM) is the cornerstone for WCM, and an integral part of any manufacturing enterprise that aspires to be world class.

The purpose of the research was to carry out an assessment of alignment of maintenance practices to TPM best practice within a South African Conglomerate. The study identified current maintenance practices, challenges faced, and gaps that required improvement. It also assessed the overall alignment of such practices to full TPM implementation. A thorough investigation of current maintenance practices was done and a clear picture was established. These practices were then compared with the ideal requirements for best TPM practice and implementation. Data for the research was obtained through interviews, performance measures from reports and a confidential on line survey.

Poor industrial relations, insufficient records keeping and aged equipment without any manuals all rendered it difficult to implement TPM. The results revealed that the conglomerate was in the process of implementing a maintenance program however the maintenance practices in place were not fully aligned to the requirements of TPM.

Dedication

This research is dedicated to my wife Emmaculate and my children, Blasio, Shingairai and Tinevimbo. I will forever treasure your love and support.

Acknowledgements

Firstly, I thank the Almighty for granting me this life to be able to pursue this dream. My sincere gratitude goes to my Supervisor, Ms Teresa Hatting for her consistent inspiration and priceless guidance. It was difficult to combine the passion for education and work requirements.

Sincere appreciation also goes to the University of Witwatersrand for affording me the opportunity to do this research. I would also like to heartily thank my employers for granting me the permission and support to further my career.

Special mention goes to the wonderful couple, Mugove and Tonde for giving me invaluable ideas to carry out this research. Lister Mutakati and Dr Isaac Takaidza, your contributions played a big role in making this dream come true.

Lastly, my deepest gratitude goes to my family for the boundless encouragement and belief in me.

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Nomenclature

A	Availability
AIDC	Automotive Industry Development Centre
AM	Autonomous Maintenance
CMMS	Computerised Maintenance Management System
FET	Further Education and Training
JIPM	Japanese Institute of Plant Maintenance
MP	Maintenance Prevention
MTBF	Mean Time between Failures
MTTR	Mean Time to Repair
OEE	Overall Equipment Effectiveness
OTDIF	On Time Delivery and In Full
Pdm	Predictive Maintenance
PM	Preventive Maintenance
PR	Performance Rate
Q	Quality Rate
RM	Reactive Maintenance
SAP	An Enterprise and Resource Planning tool
SETA	Sector Education and Training Authority
SGA	Small Group Activities
TPM	Total Productive Maintenance
WCM	World Class Manufacturing

CHAPTER 1: INTRODUCTION

1.1 Background

The purpose of maintenance in any organization is to increase availability, reliability and operability of equipment to an acceptable and sustainable cost and for the safety of employees (1). This study focused on assessing maintenance practices' alignment to Total Productive Maintenance (TPM) best practice within a conglomerate based in South Africa. Total Productive Maintenance was selected because it is one of the latest maintenance initiatives as companies move away from the traditional approach of relegating maintenance responsibilities to maintenance personnel by integrating responsibilities with Production Operators. Literature on TPM revealed that substantial benefits accrue from TPM implementation (2). This study focused on identifying gaps for TPM alignment in an organization that already has a maintenance function taking eight TPM Pillars as the yardstick to best practice (3).

A conglomerate is a large corporation run as a single business, and made up of several firms (acquired through mergers or takeovers) supplying diverse goods and services (4). Often, a conglomerate is a multi-industry company. Conglomerates are often large and multinational, and their sheer size places them in a position of influence in as far as good maintenance practice is concerned (5).

Many conglomerates have preventive maintenance systems that are intertwined with Computerised Maintenance Management Systems (CMMS). However one approach that is yet to be fully integrated into the whole maintenance package is TPM (6).

TPM is increasingly gaining prominence and recognition as mechanisation of equipment calls upon operators to be masters of everything (7). They operate the machines and maintain them to achieve the required design output, quality and speed within the time limits set for production. On Time Delivery and In Full (OTDIF) has become an important performance measure for all marketing people and can only be guaranteed in an environment where there is a good maintenance approach that results in high availability and sustained equipment reliability. Downtime has to be as low as possible.

Plant maintenance in manufacturing conglomerates is a major success contributor and it is important that this is looked at in detail to ascertain the sustainability of the organization.

1.2 Research Motivation

This research was motivated by the realisation that TPM has increasingly become important for organizations that need to improve their efficiencies. The complexities of today's production environment and the demands of markets dictate that production capacities perform at optimum capacity, producing consistently high quality products at competitive costs. The maintenance approach needs to continuously evolve to cater for the changes in world trends and industrial development, making TPM a viable solution to the challenges. It therefore was necessary to determine the extent to which one conglomerate was ready to take on board TPM principles in its maintenance approach across its business units. Due to resource constraints (time, human, accessibility and financial), only four business units were focused on to assess the effort required to achieve TPM practices for business units employing different styles and levels of maintenance within the same conglomerate.

Analysis of the results from the maintenance practices investigation offered insights into simple ways to align maintenance practices with TPM requirements leading to easier management of future TMP implementation and maintenance improvement.

The research was premised on the assumption that success in the implementation of TPM requires the presence of certain variables. These variables can be represented through a function *F* constituted as follows:

F(TPM) = *F* (P1, P2, P3, …….Pn) where Pi represents variables that determine the success of TPM implementation. While these variables are infinite, their impact on the success of TPM is different. The variables, however, all fall within the limits of TPM.

This investigation also provided an ideal matrix of the variables that need stronger emphasis for current maintenance practices to align with TPM, based on the current South African environment. The matrix of variables should be part of the methodology to implement TPM in any organization in future.

1.3 Purpose of the Study

In this research, the main purpose was to investigate the maintenance practices and identify practices that would make a business unit and hence the conglomerate fully compliant to TPM requirements. The practices were identified from a close consideration of their relationship with the eight TPM Pillars, elements of the TPM wheel and other TPM implementation methodologies.

These practices identified the gap in TMP best practices and gave an indication of what the particular business units needed to do to have a good alignment to TPM in their maintenance practices. The research identified challenges that companies face in aligning to TPM best practice, and to the best approach to TPM alignment.

1.4 Research Question

The research question that guided the study was, "To what extent are the selected business units' maintenance practices aligned to TPM best practices within the selected conglomerate?"

The research responded to the question through analysis of data collected in this investigation.

1.5 Research Objectives

The objectives of the research were to:

1. develop a framework for assessing alignment to TPM best practice within this conglomerate.
2. identify gaps to TPM best practice within the conglomerate, and
3. recommend necessary corrective actions to close the gaps.

1.6 Significance of this research

Increased globalisation and adoption of world class manufacturing practices the world over has called for shorter product life cycles, increased automation, new technology as well as innovative production systems and strategies.

This research focused on four business units within a conglomerate for possible future adoption of TPM as a maintenance strategy. It sought to determine gaps in the best practices in the current maintenance practices in the conglomerate's four business units. In light of these observations the research is useful in as far as it helps to:

1. analyse and determine whether TPM adoption will be necessary in order to allow for employee engagement, improve productivity, ensure quality improvement and facilitate organizational change, and
2. execute a maintenance approach that enables adoption of TPM as a best maintenance practice.

1.7 Research Scope and Limitations

The conglomerate involved in this research is a steel manufacturing and beneficiation concern.

The industry is very competitive and industries are therefore not very free to divulge information to third parties. This, couple with the current economic environment meant, where the local industry viability is threatened with cheap imports, meant that only one conglomerate was targeted and four business units within the conglomerate provided information that was used for this research.

It was extremely difficult to engage more companies in a similar industry because of limitations.

Four business units were analysed although a wider scope might have found a different set of results. However, confinement to only four units allowed for depth rather than mere breath of the investigation.

The research gave an indication of the extent to which the companies conformed to TPM best practices.

CHAPTER 2: LITERATURE REVIEW

The literature review considered maintenance strategies that could be pursued and key aspects of TPM as a maintenance strategy. The section also looked at the reasons why companies were adopting TPM and the resultant benefits that accrued from the use of TPM.

2.1 Purpose of Maintenance

Catastrophic failures are a big cost to industry, and a company's profitability is affected if the plant is not able to produce because of breakdowns. An unplanned outage costs 30 times more than a stoppage that is properly planned (6). System availability is becoming a very critical issue in any organization and the need for optimum maintenance schedules and reduction of operating costs has become more and more pronounced (8).

Coetzee (1) states that "*It is the task of the maintenance function to support the production process with adequate levels of availability, reliability and operability at an acceptable cost*".

The objectives of maintenance are subdivided into four sub-objectives:

1. Availability: This is defined as the proportion of time that a technical system or a machine is in an operable state. This implies that the machine is ready for production in the event that it is needed and hence any maintenance function must provide an adequate level of availability to meet the production plan demands (1).
2. Reliability: This is a measure of the number of times that the technical system or machine experiences problems (1). It is an indication of the continuity of the production process. As such it is possible to have high availability but poor reliability resulting in start stop effects that can impact on quality and costs. High availability and high reliability are necessary for any maintenance function to guarantee a company's success.
3. Operability: This is defined as the technical system's or machine's ability to sustain adequate (as per design) production rates (1). While high availability and reliability are important, they cannot produce positive results if the system's operability is poor.
4. Cost: Any maintenance function can only be carried out if cost implications are tolerable (1). Cost optimization is a premise for any maintenance strategy.

In a manufacturing environment, there may be a tendency to view maintenance issues as limited to output, unit costs, and efficiencies only, and yet maintenance transcends such factors to include end product quality, process control, ergonomics and safety of employees, as well as compliance to regulatory issues such as environmental, structural integrity, and the physical appearance of the production system.

2.2 Types of Maintenance Strategies

This section highlights some of the major maintenance strategies leading to the choice of TPM as the best option. Swanson (9) states that maintenance is divided into three approaches which are Reactive, Proactive and Aggressive maintenance.

2.2.1 Reactive Maintenance

In a reactive maintenance (RM) system, the maintenance function responds to malfunctions and breakdowns (1). Emphasis is placed on speedy resolution of issues and bringing the plant up as soon as possible. More often the repair is temporary in nature. As such RM is considered the least efficient mode of all maintenance strategies though in some cases it can be cost effective (1) (9). Its other main disadvantage is unpredictability leading to huge variations in productivity and costs thereby affecting planning. (9)

2.2.2 Proactive Maintenance

Proactive maintenance is divided into preventive maintenance and predictive maintenance (9). Preventive Maintenance (PM) activities are designed to prevent equipment failures and ensure reliability (1). PM tasks are use-based and are performed at pre-determined periods with established methods, tools equipment and time estimates (1) (9). Examples are equipment checks, parts replacement, machine adjustments, overhauls or rebuilds, and cleaning. The aim is to maintain the equipment as new or within its specified designed parameters possible.

PM is also a good precursor to Autonomous Maintenance (AM) since some of the activities can be done by production operators (10). Predictive Maintenance (PdM) is the periodic measurement or trending of process or machine parameters with the aim of predicting failures before they occur (1). PdM, also referred to as condition based maintenance, is initiated in response to equipment

condition (9). Emphasis is placed on the use of diagnostic equipment to measure physical condition of equipment such as temperature, vibration, noise, lubrication and corrosion. PdM is a triggering mechanism for action with most tests performed while equipment is in operation. This avoids carrying out maintenance activities too early or too late and thereby saving costs (9).

2.2.3 Aggressive Maintenance

Aggressive maintenance aims to improve the function and design of the production equipment (9). It goes beyond the need to avoid equipment failures and seeks to improve overall equipment operation. TPM is one such approach (9). The old adage of slow but sure is not applicable to TPM since improvement must be rapid and continuous (9). This is meant to have a competitive advantage in a sustainable manner (5).

2.3 Introduction of TPM

Since 1971, the Japan Institute of Plant Maintenance has placed emphasis on the concept of total involvement of all company personnel in equipment and asset management through TPM (11).

Various definitions have been given for TPM. Nakajima defines it thus

"TPM is a *plant improvement methodology* which enables *continuous and rapid improvement* of the manufacturing process through the use of *employee involvement*, *employee empowerment*, and *closed-loop measurement of results*" (12)

TPM is about improvement that is continuous, fast, measured and involves employees. It is also defined as a companywide equipment maintenance system involving all employees, from top management to production line workers and the building custodians.

The word Total in Total Productive Maintenance is linked with the following (13):

- *Total Equipment Effectiveness* in pursuit of business profitability and not just reducing maintenance costs.
- *Total Maintenance System* and this encompasses Maintenance Prevention (MP) – at equipment design, Maintainability Improvement (MP) – during equipment use and Preventive Maintenance (PM) – as strategized for the equipment's entire life span.

- *Total Participation* by all employees from the shop floor to top management.

TPM is about management of plant assets in a structured way to bring about the necessary improvements. It can still be complimented with other improvement processes such as Total Quality Management, Formal Benchmarking or Theory of Constraints.

2.3.1 Origins of TPM

Total Productive Maintenance, TPM, was first used in the late 1960s by a company called Nippondenso, a supplier of electrical and electronic components to Toyota in Japan.

The slogan for their plant improvement theme was, "productive maintenance with total employee participation" (11). The company ended up receiving an award for their maintenance efforts from the Japan Institute of Plant Maintenance (JIPM) in 1970 (11). TPM is considered an evolution of preventive maintenance, originally conceived in the United States in the 1950s. According to Rodrigues (3), it is an evolution of maintenance technology methodologies known as: Latin School (France—middle 1960s), Russian Investigations (Russia—end of 1960s) and Terotechnology (England—beginning of 1970s).

Seeichi Nakajima, then President of JIPM, took over the fine tuning and implementation of TPM across many Japanese companies and he is considered the father of TPM (14) (15). TPM began as a vital and necessary response to business imperatives to reduce waste, product variation and product cycle times (14). This meant that companies were obliged by the competitive environment to draw attitudes that ensured the best performance of the equipment, reduced interruptions or production stoppages and continuously redefined goals.

Nakajima further adds that, in organizations where TPM has been applied, productivity gains of up to 60% have been documented (12).

2.4 TPM studies and Resultant Benefits

TPM has inherent benefits that companies can use for improvement of maintenance performances and productivity improvement. McKone states that TPM changes the structure of the organization, breaks down traditional barriers between maintenance and production, fosters improvement by looking at multiple perspectives for equipment operation and maintenance, increases technical

skills of production personnel, includes maintenance in daily production tasks as well as long-term maintenance plans, and allows for information sharing among different functional areas (2) (7). TPM should therefore, develop the capability of the organization to identify and resolve production problems and subsequently improve maintenance prevention. Employees are all proactively involved in the maintenance of machines which leads to increased productivity, lower costs, improved quality and extended machine lifespan (16)**.**

The following are some studies that have revealed the benefits of TPM. TPM has already been proven to be a good asset management practice (5) (9) (15). In Mckone et al.'s (2) (7) survey of 117 plants across three industries spanning four continents, a direct relationship between the companies that implemented TPM and a positive manufacturing performance was found. The investigation revealed that TPM had a positive and significant relationship with low cost (as measured by higher inventory turns), high level quality (as measured by higher levels of alignment to specifications), and strong delivery performance (as measured by higher percentage of on-time deliveries and by faster speeds of delivery).

Gupta et al. noted in their study that, after TPM implementation, availability improved from 80% to 85.1%, efficiency improved from 76.9% to 83.1%, and quality improved from 95.5% to 99% (15). This meant that the OEE (Overall Equipment Effectiveness) improved from 58.7% to 70%.

Another study by Kumar et al. (17) also noted the following benefits as depicted in Table 2.1.

Table 2.1 Tangible TPM results (17)

S.No.	Attributes	Before TPM	After TPM	Improvements
1	Profit	150 Millions of Rupees	300 Millions of Rupees	100%
2	Sales Turnover	1000 Millions of Rupees	1600 Millions of Rupees	60%
3	Production Cost	69% of sales	60% of Sales	9%
4	Plant OEE	62%	90%	28%
5	Plant Labour Productivity	80%	90%	10%
6	Breakdown Frequency	28%	7%	21%
7	Defect Rate	6%	2%	4%
8	Customer Complaints	850	55	93%
9	Delivery Rate	81.6%	97%	15.4%
10	Inventory	250 Crores of Rupees	125 Crores of Rupees	50%
11	Labour Accident	2	0	200%

The application of TPM resulted in improvements that were both tangible and intangible and these were (17)**:**

- increase in team spirit and group behaviour in operators and staff
- development of clean, dry, bright, visual and likeable work places
- appreciation from customers and other visitors during plant visits
- multiskilling abilities done by operators
- increase in the ownership of equipment and workplace by the operator, and
- increase in confidence of their ability to perform complex jobs/problems by operators and staff.

In South Africa, under the auspices of the Automotive Industry Development Center (AIDC), a TPM ClubSA was established and a pilot implementation of TPM was initiated. By the end of 2014 it had launched TPM within automotive related companies all over South Africa, working as TPM clusters (18). Savings of R16million were realized across the companies and specifically 6 suppliers realized “in excess of R7million over the first 4 months” (18)**.**

The main emphasis of the TPM clusters was Autonomous Maintenance and Focused Improvement since they had realized that minor stoppages were contributing to down time and inefficiencies. The study revealed spin offs that were realized by the introduction of Autonomous Maintenance

and Focused Improvement initiatives over the period. Veyance Technologies, one of the companies, for instance reduced scrap by 75% and breakdowns by 73% over a period of six months. (18)

Natstan, another of the companies, increased its output by 42%, and decreased quality defects by 33% (18). A third company, SJM Flex improved output by 55% and reduced cleaning time by 70% (18)**.**

2.5 Maintenance Evolution Leading to TPM

Two authors Tarita (19) and Risner (20), present charts on the progression of maintenance. Tarita includes the gradual progression over the years while Risner gives generic stages that a company goes through over a period in order to reach the TPM level. These two provide a clear picture for analysis, and allows a company to check where it is and the implications of its maintenance practices. The charts are presented on Figures 2.1 and 2.2. The gradual progression of maintenance over time is best depicted through the road to excellence model as proposed by Tarita in Figure 2.1.

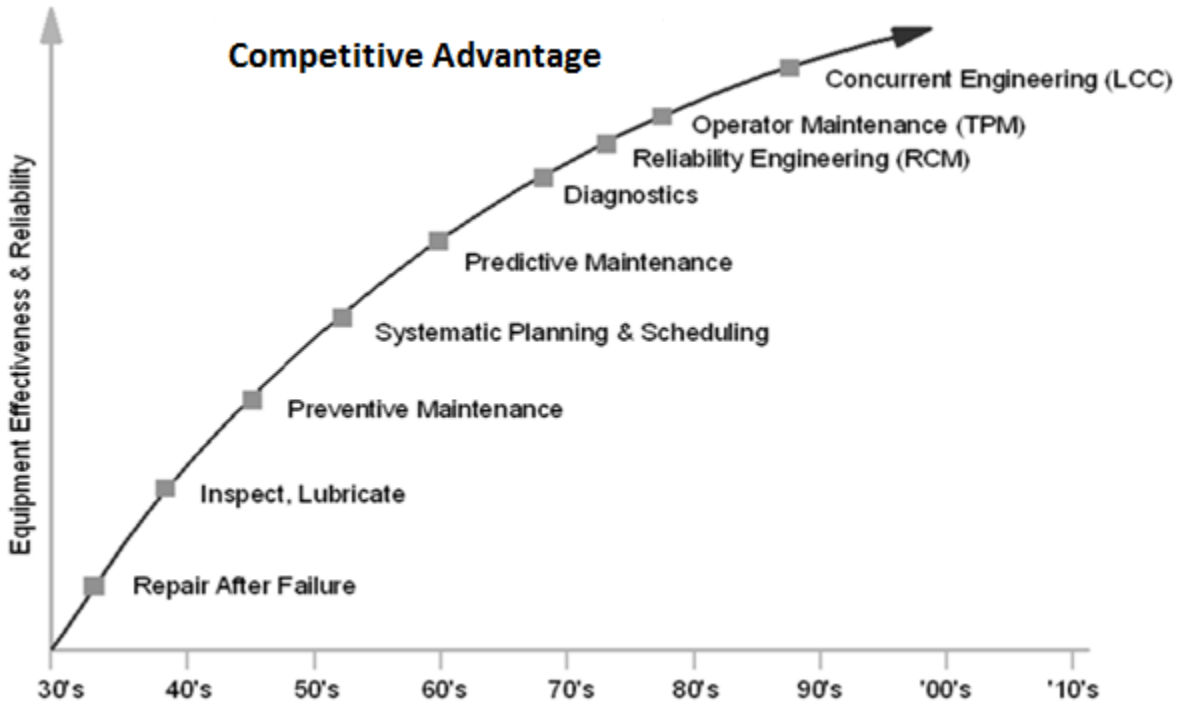


Figure 2.1 Evolving strategies for equipment operation and maintenance (19)

The increase in equipment effectiveness and reliability occurs in tandem with competitive advantage. Prior to the 1940s, emphasis was on repair after failure, and inspection and lubrication.

After the 1940s, preventive maintenance came in and systematic planning and scheduling were introduced a little later, just before the 1960s. From the 1960s to 1980s came the concepts of predictive maintenance, diagnostics, Reliability Engineering (Reliability Centered Maintenance) and Operator Maintenance (Total Productive Maintenance). Concurrent Engineering (Life Cycle Costing) came around the 1990s. Total Productive Maintenance encompasses Just in Time (JIT) manufacturing, Lean Management, Total Quality Management (TQM) and Design to achieve minimum life cycle cost (14). Quality of maintenance has a strong bearing on business profitability, which has a direct link to safety and customer service, and plant costs and availability (6) (2) (8)**.** Increased downtime has an adverse effect on the average rate of output (speed), thereby increasing operating costs and lowering customer's satisfaction (3)**.**

Tarita's (19) concept also tallies in with the study done by Risner (20), where the following "Evolution of Maintenance chart" on Figure 2.2 emerged.

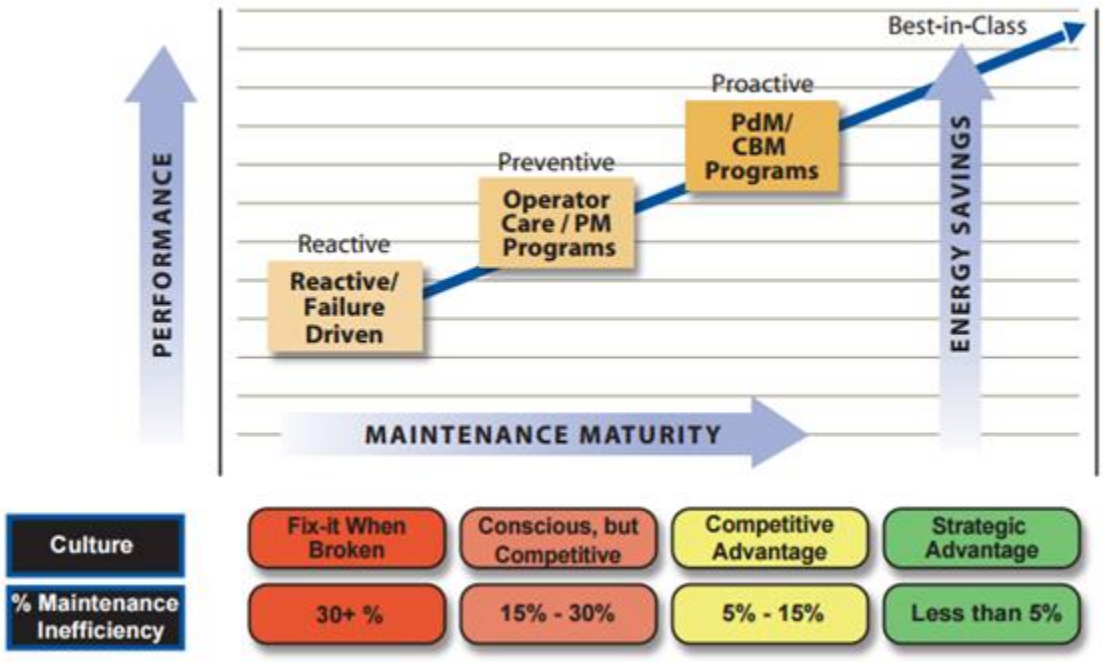


Figure 2.2 Evolution of maintenance: Risner (20)

Risner, like Tarita has vertical axis as Performance which Tarita refers to as Equipment Performance and Effectiveness. Tarita mentions competitive advantage on the horizontal axis which Risner refers to as maintenance maturity which is still measured in terms of the strength of competitive advantage. While Tarita is specific about the actual period when maturity of each stage happens, Risner provides the ideal stages each organization is expected to go through in the quest for improvement. Risner basically mentions that maintenance evolves from Reactive to Preventive, then Proactive and finally, to best in class. A look at the horizontal axis shows that both authors identify TPM as a practice that results in competitive advantage.

2.5.1 Design, Maintenance and Production Interface

It is very important to understand the relationship among maintenance, production and the manufacturer of equipment. A maintenance problem framework as developed by Coetzee (1) , clearly shows the triangular relationship among machine designer, the production's use of the machine, and the maintenance of the machine.

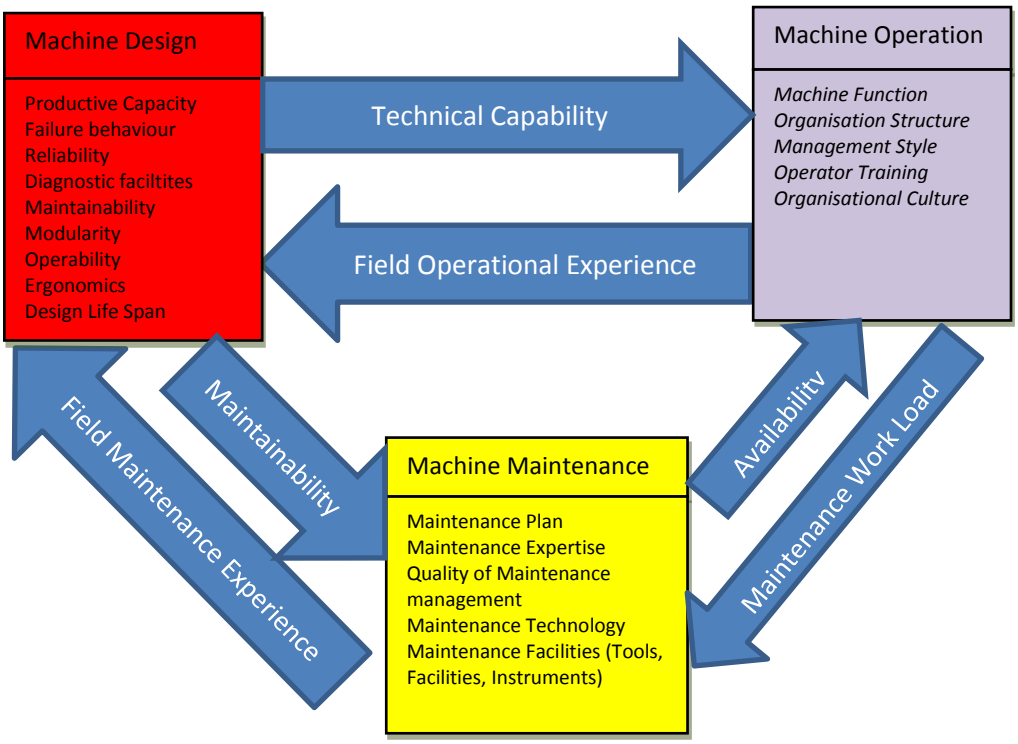


Figure 2.3 Maintenance problem framework (1)

Firstly, the designer plays the key aspect of designing and meeting the production parameters. He covers aspects of the equipment's failure behaviour, reliability and maintainability. Secondly, the production function affects the machine's maintenance requirements through utilization of the machine to meet production requirements. Such use also covers possible extremities such as abuse of the same. In the third place, the machine's continued production performance is determined by the effectiveness of the maintenance that it is subjected to hence forth. This hinges on the maintenance plan applied, the craftsmanship and the maintenance quality deployed.

There is a cross functional relationship where the designer / manufacturer provides the technical capabilities while the machine operator and the maintenance function provides the field operational and maintenance experience to the manufacturer. The maintenance function mainly provides availability of the equipment to production through maintaining the inherent reliability and operational status of the equipment. The cross functional relationship naturally leads to the adoption of TPM as a maintenance approach that manufacturing companies must adopt in order to improve their operational efficiencies and subsequent spin offs.

The above is in line with Nakajima's definition of TPM (12). He defines TPM as a maintenance system, which covers the entire life of equipment in every division including planning, manufacturing, and maintenance. He describes a synergistic relationship among all organizational functions, particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity assurance and safety.

2.5.2 The TPM wheel -Seven broad elements of TPM

There are seven broad elements that run a common theme in any TPM program (6). These elements are generally depicted in a circular fashion in order to show continuous improvement effort.

The elements are:

1. Asset strategy
2. Empowerment
3. Resource Planning and Scheduling
4. Systems and Procedures
5. Measurement
6. Continuous Improvement Teams
7. Processes

These elements are shown on the TPM wheel depicted in Figure 2.4.

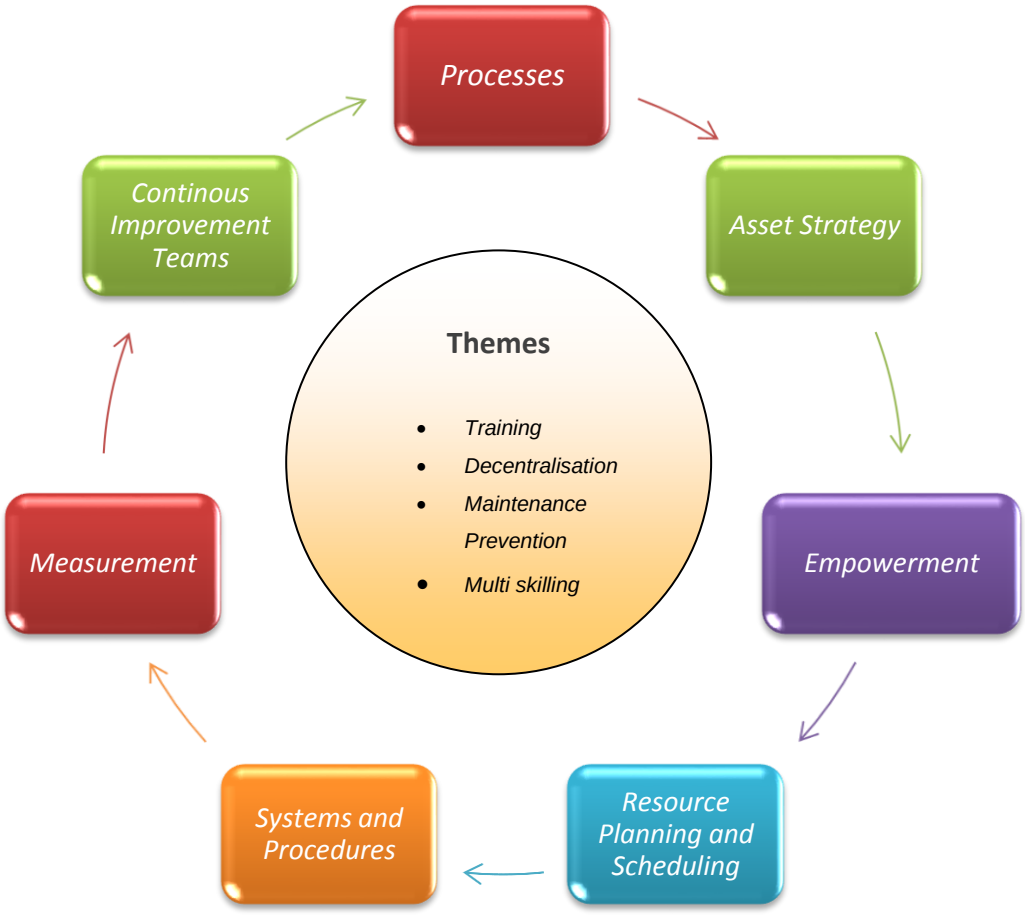


Figure 2.4 TPM wheel (4)

All the seven elements depicted above have at the core, the four themes of Training, Decentralization, Maintenance Prevention and Multi-skilling.

1. **Asset Strategy**

   The maintenance structure is meant to support the new Asset management strategy in terms of layout designs, equipment modifications and Preventive Maintenance program review. The Asset strategy can be linked with the maintenance problem framework already explained in Figure 2.1.

2. **Empowerment**

   TPM places the power to improve in the employee's hands. As such there is need to create an enabling environment for employees that grant them both autonomy and responsibilities. This is done in the spirit of continuous improvement.

   TPM encourages multi-skilling and exchange of ideas between operations and maintenance, and can fundamentally change an organization's culture. Centralized, command-and-control maintenance structures cannot support TPM since TPM is supposed to be dynamic.

   Operators must be encouraged to take pride in owning and managing their assets and offer visible evidence of the improvements noted in both skills and understanding of the operations of their equipment.

3. **Resource Planning and Scheduling**

   The maintenance department will be called upon to expend as much energy as possible in training and getting operators to understand their equipment and the reasons for chronic failures. Resource planning and scheduling is a critical element especially during the initial implementation stages.

4. **Systems and Procedures**

   The focus on equipment performance will also result in the evolution of best operating and maintenance practices. This will result in the need to have an effective data management system that captures and tracks the history of equipment information and essentially mitigate or reduce the risk of failure. Tactics of maintenance will therefore improve based on these systems and procedures.

5. **Measurement**

   In order to note any changes, the yardstick will be to compare reality against a future vision. Improvements, as measured by TPM teams themselves will result in motivation of employees striving for excellence. The single most important measure is OEE but there are other measures that can be used for good practice or set as targets. The measurements must be visible and shared for the benefit of all stakeholders.

6. **Continuous Improvement Teams**

   Kaizen or Continuous improvement remains a key component of any TPM program. TPM teams are established to deal with failures and avoid recurrence. These improvement teams base their agenda on available equipment history and such records provide invaluable information for the teams' effort. The use of pareto analysis of causes of failure allows the teams to focus on the critical issues and thoroughly deal with them.

7. **Processes**

   While the traditional maintenance processes has had preventive, corrective and breakdown maintenance, with the stores department responsible for inventory control, TPM calls for a radical approach to such processes. The new TPM climate calls for responsiveness, flexibility and empowerment and hence continuous revision of the traditional approach to something that eliminates waste of any form but adds value to the process.

2.6 Eight Pillars for TPM Implementation

While the seven elements explained above are critical in the implementation of TPM, the following eight pillars have been identified as the backbone for TPM implementation. 5S is the basic foundation of the TPM Pillars (16)**.**

2.6.1 TPM and 5S

5S is considered the foundation of TPM because without 5S, any organization that intends to implement TPM will flounder under the weight of disorganization, indiscipline and inefficiency (16). These "5S"s are also referred to as pillars of Autonomous Maintenance in some texts (5) (15). The "S"s are explained below (21).

1. Sorting: Sort out and separate that which is needed and not needed in an area.
2. Straighten: Arrange items that are needed so that they are ready and easy to use. Clearly identify locations for all items so that anyone can find them and return them once the task is completed.

3. Shine: Clean the workplace & equipment on a regular basis in order to maintain standards & identify defects.
4. Standardise: Revisit the first three of the 5S on a frequent basis and confirm the condition of the ***Gemba*** using standard procedures.
5. Sustain: Keep to the rules to maintain the standard and continue to improve every day.

The benefits of 5S will be improved safety and a continual quest for improvement. Waste in all its forms is also reduced, and increased productivity, quality and morale leads to improved profitability. Rodrigues (3) and Gitachu (16) propose the following eight pillars for TPM shown on Figure 2.5.

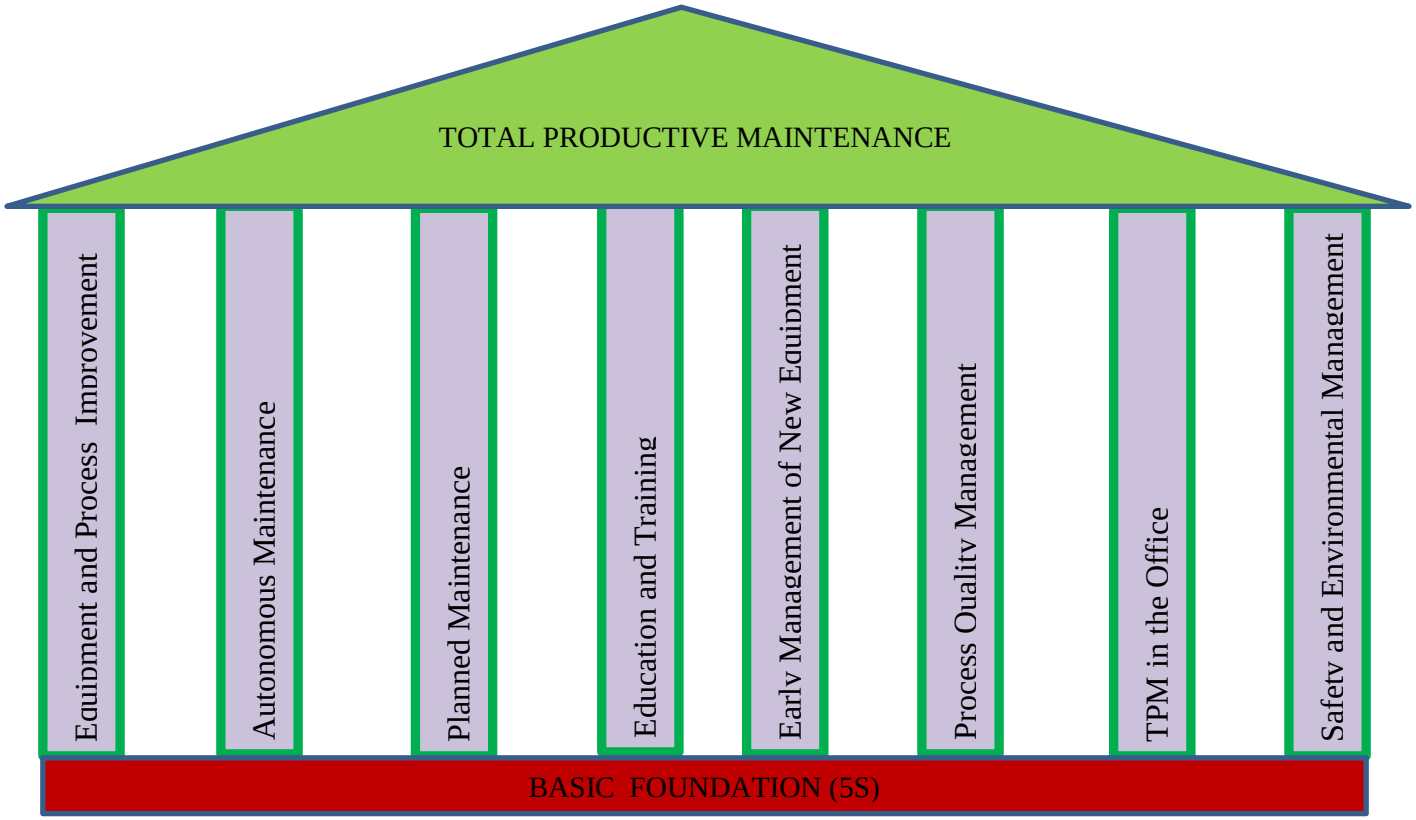


Figure 2.5 The eight pillars of TPM (3)

Each pillar encompasses the following

- Equipment and process improvement - places emphasis clearly on the vision for improvement in the business. It is also referred to as Focused Improvement or Kobetsu-Kaizen (22) . It focuses on OEE analysis and improvement with focus on losses.
- Autonomous maintenance - also referred to as Jishu-Hozen (22). Places emphasis on self-management and control, creating awareness of the TPM philosophy. It encourages Operators to maintain their equipment thereby creating a sense of ownership. The seven steps of Jishu Hozen are explained in the figure 2.6.
- Planned maintenance or Keika-Hozen (3) (22) - Covers the aspects of effective planning and control of maintenance including daily planning of maintenance activities and stoppages. It also encourages investigating root causes of downtimes to avoid recurrence of problems.
- Education and training - Building up team work, technical and management skills of maintenance personnel and operators.
- Early management of new equipment - Involvement of maintenance in the conception of new projects and acquisitions. This reduces prototype lead times and improves life cycle costing. (22) (3).
- Process quality management or Quality Maintenance / Quality Hozen - These are activities that lead to zero defects (3). The emphasis for this pillar is on quality assurance and investigating quality defects (22).
- TPM in the office - Administrative involvement in the efficient implementation and delivery of the TPM program.
- Safety and environmental management - Having systems to establish a healthy, safe and sustainable work environment. Emphasis is placed on achieving zero accidents and the creation of a healthy, rewarding and pleasant work environment (22).

JMAC Consultants (22) also added on the goals, responsibilities and actions that are associated with these pillars in the implementation of TPM as a system of maximizing production and effectiveness.

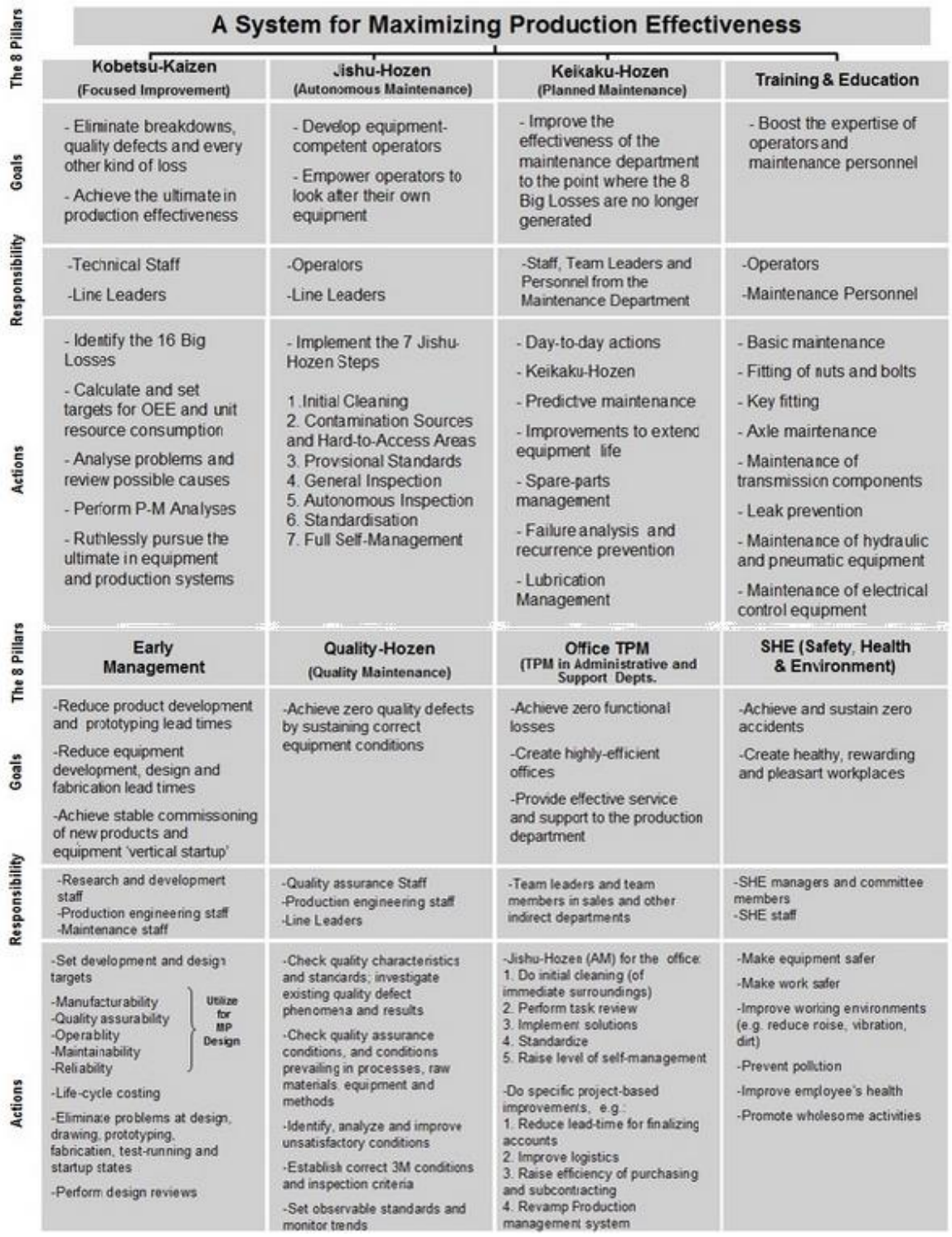


Figure 2.6 Brief summary of the 8 TPM pillars (22)

The pillars form a system for maximizing effectiveness and as such, no pillar can be chosen as the strongest one but they pull together in a quest for continuous improvement. The combined use of the TPM wheel and the eight TPM pillars makes it easier for TPM implementation. It is a people driven process. Jonsson (23) mentions that TPM development is based on human factors, and is supported by top management and an effective information system.

2.7. Autonomous Maintenance

Autonomous Maintenance (AM) is the process by which equipment operators accept and share responsibility (with maintenance) for the performance and health of their equipment (11). Operators are trained to carry out some activities that prevent catastrophic failures, especially equipment inspection, cleaning and lubrication. TPM calls an enterprise to have a team of maintainers and operators working together to make equipment reliable.

While traditionally an operator's emphasis has always been placed on production output, TPM goes further to make the operator responsible for the quality of the product and how such quality is achieved. This calls for groups or teams working together to meet the basic primary goal of TPM which is to produce quality products at the time and the rate required (6). As such the concept of Small Group Activities (SGA) is brought to the fore in the implementation of TPM.

The following are three distinct features of TPM.

1. Activities to maximize equipment effectiveness.
2. Autonomous maintenance by operators.
3. Small group activities.

Achievement of high equipment effectiveness requires elimination of failures, defects and any other form of waste or loss incurred in equipment operation. TPM utilizes the concept of Overall Equipment Effectiveness as a common key measure for both maintenance and operations. It also encompasses the elimination of six big losses; a subject which will be discussed later under a separate section.

Small group activities foster teamwork as players from other departments such as quality, production, maintenance and engineering work together to promote continuous improvement.

Chana (14) proposes the following frame-work to demonstrate the importance of the interaction between maintenance and operations in an autonomous maintenance environment. Such an environment cannot be created where there is no harmonious relationship between management and employees since one has to deal with the notion that operators might end up saying that they are doing an artisan's job.

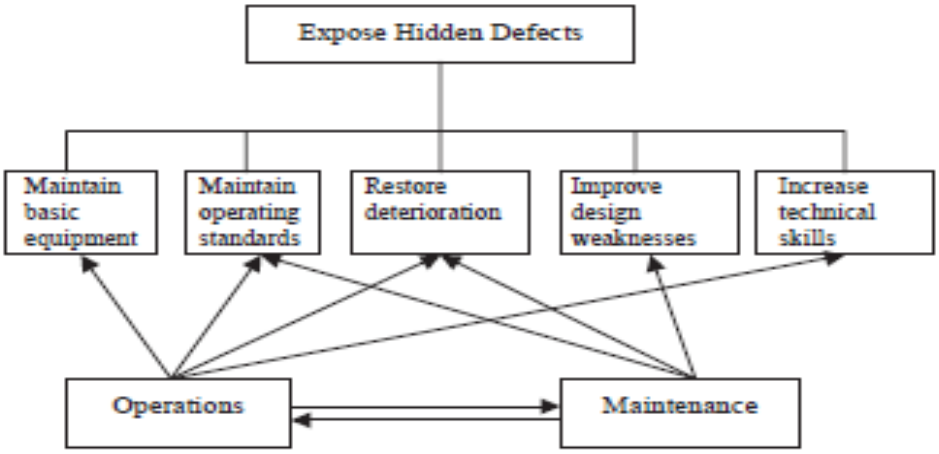


Figure 2.7 Relationship between operation and maintenance (14)

The Operators will be involved in the following processes as a small step to AM.

- Ensuring that equipment is operated on a sustainable basis. This implies that Operators have a role to run the equipment properly, without abuse, or through running over the set range of parameters. This can also be achieved through visual inspection as equipment deteriorates.
- Carrying out basic tasks that ensure that equipment is available. The basic tasks that operators must of necessity do are cleaning, lubricating and bolting.
- Playing an active role in noting deteriorations particularly through visual inspections and noting adverse trends on performance.
- Improving operator skills on equipment operation, set up, adjustment as well as visual inspection.

If Operators are able to carry out Autonomous Maintenance in the above manner, then maintenance personnel will have time to:

- provide technical support for the AM system
- address equipment deterioration thoroughly through the use of condition monitoring, inspections and equipment overhauls.
- spend more time on improvement initiatives, tracing equipment design protocols and noting areas of weakness that need improvement, and
- enhance skills improvement of maintenance personnel in the areas of equipment check-up and inspection, condition monitoring and overhaul.

2.8 TPM Implementation

Various authors have proposed various ways of TPM implementation. TPM focuses on optimizing planning and scheduling (24). Gupta further states that TPM entails having the following (24):

- Linear Organizational Structure
- Multi skilled workforce
- Rigorous reappraisal of the way the thing is done so that improvements are introduced, resulting in simplification and / or standardization.

This also correlates with the 7 elements of TPM implementation explained earlier in figure 2.4.

TPM is a “top-down” exercise but typically implemented through a “bottom-top” implementation strategy (8). This is because top management has to decide the modalities of implementing TPM while the actual execution of implementation has to start from the shop floor. In their study, Chan (14), proposes the utilization of all the 8 pillars of TPM whereby TPM in the office integrates with human resource pillars like Training. The major focus was for Production to lead the TPM process rather than Maintenance. TPM implementation was initially targeted at one machine and more were added as it developed. It basically went through the following 12 step system, subdivided into four critical stages as explained Table 2.2.

Table 2.2 Twelve steps for TPM implementation program (14)

Introduction-preparatory stage

Step 1:The top person's declaration of the resolve to introduce TPM
The declaration is made in an internal TPM lecture meeting, and should be printed in an internal bulletin or newsletter
Step 2:TPM introduction education and campaign
Managerial staff: Staff of the same echelon are scheduled together for training
General employee: Slide-show meetings
Step 3:Formation of TPM promotion organizations and formal organizational models
Committees, specialised subcommittees, promotion secretariat
Formal organization models
Step 4:Setting of basic TPM principles and targets
Benchmarks and targets; prediction of effects
Step 5:Preparation of a master plan for implementation of TPM
From preparation for introduction to undergoing examinations
Start of Introduction
Step 6:Kick off TPM
From preparation for introduction to undergoing examinations
Introduction-execution stage
Step 7:Establishment of a system for improving the efficiency of the production department
Step 7.1:Kobetsu –Kaizen
Project-team activities and workshop small-group activities
Step 7.2:Jishu Hozen
Step method, diagnosis, approval certificates
Step 7.3:Planned maintenance
Corrective maintenance, periodic maintenance, predictive maintenance
Step 7.4:Operation /maintenance skill development
Collective education of leaders and education concerning transmission of education to members
Step 8:Establishment of initial phase management systems for new products and new equipment
Development of easy-to-manufacture products and easy-to-use equipment
Step 9:Establishment of quality maintenance systems
Creation of conditions in which defects do not occur, and the maintenance/management of those conditions
Step 10:Creation of systems for improvement of the efficiency of administrative/indirect departments
Production support, improvement of the efficiency of related sectors, and improvement of efficiency of equipment
Step 11:Creation of systems for the control of safety health, and the environment
Creation of systems for zero accidents and zero pollution cases
Establishment stage
Step 12:Complete implementation of TPM and level improvement
Undergoing examinations for the receipt of PM awards
Setting sight on higher targets

Gupta (24) emphasizes that the organizational structure is important for the success or failure of TPM implementation. Effective leadership is required from the top to drive the implementation process. He divides the 12-step implementation of Chan (14) into five main themes which are:

- Accomplishing TPM acceptance,
- creating TPM support from Management, Unions and employees,
- creating enthusiasm and positive expectations from TPM,
- developing a realistic custom implementation plan, and
- accomplishing world class results in a timely manner.

The Gupta implementation method is shown in Table 2.3:

Table 2.3 Gupta Implementation method (24)

Main Theme	Activity Step	Methodology
Accomplish TPM Acceptance	Announcement of Top Management decision for the implementation of TPM	Use of magazines, newsletters, promotions etc. by management to ensure the buy-in of TPM from the start.
Accomplish TPM Acceptance	TPM education program and collection of information	For informing and educating everybody in the organization about TPM.
Create TPM support from Management, Unions and employees	Establishment of an organizational structure	Team based activities meant to sustain and promote established TPM norms and culture.
Create enthusiasm and positive expectations from TPM	Formulation of basic TPM and goals	Review current activities and create realistic, measurable, attainable, results oriented and specific goals and policies to ensure improvement.
Create enthusiasm and positive expectations from TPM	Presentation of Master Plan for TPM deployment	What follows after the establishment of policies and goals is a presentation of the master plan for TPM deployment. This is done based on the situation and acceptance of TPM on the shop floor
Create enthusiasm and positive expectations from TPM	Conduct and presentation of feasibility study results	The feasibility study is done by selected teams with particular emphasis on OEE. The results of the study should be used as motivation to do better leading to the next step of piloting.
Develop a realistic custom implementation plan	Implementation of the pilot installation process	The pilot installation proposes that 10-25 percent of the plant must be covered, not just a few selected machines. Clear goals and objectives are important and team meetings are crucial
Develop a realistic custom implementation plan	Implementation of the Plant wide installation process	This is not pilot success dependent but time dependent. Within three months of pilot installation, teams must cover the rest of the plant in a staggered manner.
Accomplish world class results in a timely manner	Introduction Audit	This is the first audit, typically done 6 to 12 months after implementation just to check progress and confirm if the fundamentals are in place.
Accomplish world class results in a timely manner	Progress Audit	This is done 18-30months after launch and is done typically to determine if and how: Preventive maintenance is done by TPM teams Equipment improvement activities have been executed according to schedule Increase in OEE has been reached Improved equipment condition has been achieved and documented The planned level of skill has been achieved.
Accomplish world class results in a timely manner	Certification	This is done to confirm and certify that the TPM system meets international standards.
Accomplish world class results in a timely manner	TPM Award	This marks the seal of approval that the company is truly world class.

Both Gupta et al (24) and Chan (14) follow the same steps in terms of implementation. The only difference is that Gupta advocates company -wide installation while Chan emphasises pilot equipment. All the 12 steps have the same objectives and approach.

2.9 Maintenance Performance Process and Measurement Review

Performance measurement is a fundamental principle of management (25). In any organization, the maintenance process or effort delivers the maintenance performance measures that will be analysed (26). Moreover, without having a formal measurement system for performance, it is difficult to plan, control and improve the maintenance process (26).

Overall Equipment Effectiveness (OEE) is used as a key performance indicator for the manufacturing industry in its continuous search for new ways to reduce downtime, costs and waste, and to achieve greater capacity utilization.

To develop a structured approach of measuring performance of the maintenance function, it is imperative to have a well-formulated maintenance strategy based on corporate and manufacturing strategy. The approach should then encapsulate a coherent theory of maintenance processes that are critical success factors to manufacturing and business success (25).

According to Muchiri (25), the maintenance function has four basic steps and these are; Work Identification, Work Planning, Work Scheduling and Work execution. Each of these steps has key performance indicators that have to be monitored at each and every stage. He proposes the following frame work of maintenance performance measures.

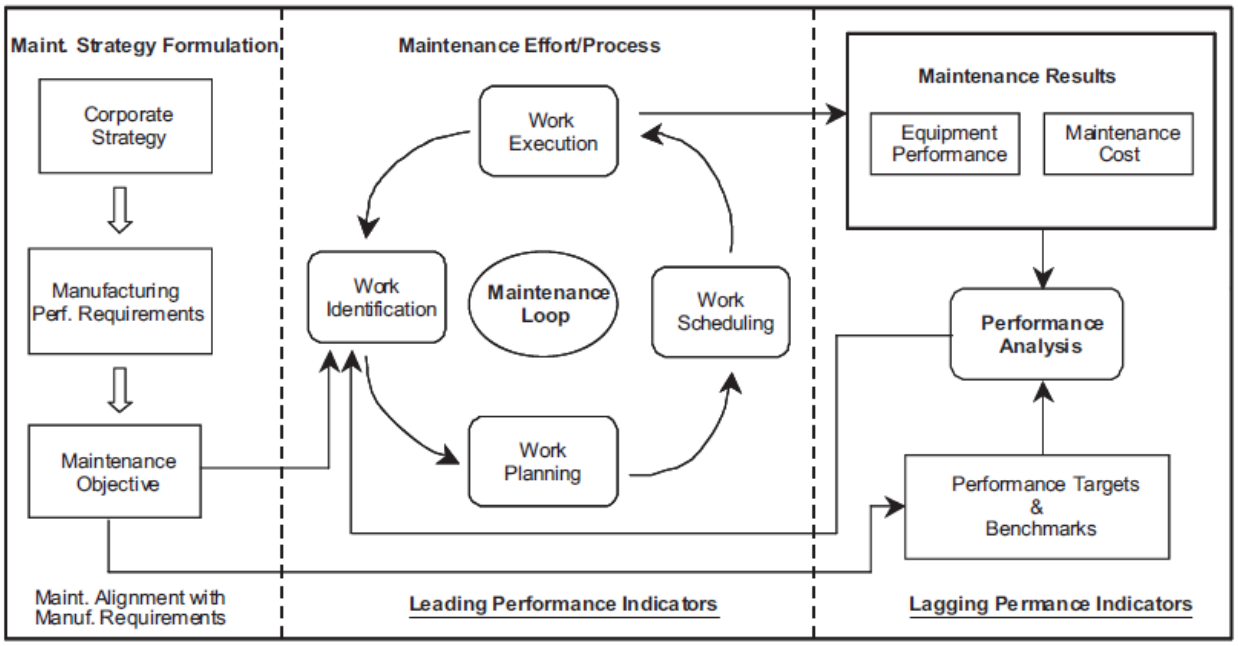


Figure 2.8 The performance measurement framework for the maintenance function (25)

There is a clear link established between the key steps of the Maintenance Strategy Formulation, Maintenance Effort / Process and the Maintenance Results. All three are intertwined.

2.9.1 Leading and Lagging Indicators

Leading indicators measure the maintenance process to monitor if the process is being done well. They are leading because they measure processes that lead to the results. They are a measure of pro-activeness in terms of maintenance execution. On the other hand, lagging indicators measure the results of the maintenance process. They give the results of the Reliability, Availability and Operability of the technical system. (25)

Tables 2.4 and 2.5 categorize the necessary performance measurement indicators as per the maintenance process and results already explained by Figure 2.8.

Table 2.4 Common leading indicators (25)

Category	Measures/ Indicators	Units	Description	Recommended Targets
Work Identification	Percentage of Proactive Work	%	Man-hours envisaged for proactive work/Total man hours available	75%-80%
	Percentage of Reactive Work	%	Man-hours for reactive work/Total man hours available	10%-15%
	Percentage of Improvement work	%	Man-hours for improvement & modification/Total man hours available	5%-10%
	Work response request rate	%	Work requests remaining in "request" status for <5days / All WO	80% of requests
Work Planning	Planning Intensity Rate	%	Planned Work done/Total Work done	95% of all WO
	Quality of Planning	%	Percentage of Work Orders requiring rework due to planning/All WO	<3% of all WO
	Planning Responsiveness	%	Percentage of WO in planning status for <5days/All WO	>80% of all WO
Work Scheduling	Scheduling Intensity	%	Scheduled man-hours/Total Available man-hours	>80% of available man-hours
	Quality of Scheduling	%	Percentage of WO with delayed execution due to material and man-power	<2%
	Schedule Realization Rate	%	WO with scheduled date earlier or equal to late finish date/All WO	>95% of all WO
Work Execution	Schedule Compliance	%	Percentage of work orders completed in scheduled period before late finish date	>90%
	Mean Time To Repair (MTTR)	%	Total Downtime/No. of Failures	
	Manpower Utilization rate	%	Total Hours spent on tasks /Available Hours	>80%
	Manpower Efficiency	%	Time Allocated to Tasks / Time spent on tasks	
	Work Order Turnover	%	No. of completed tasks / No. of received tasks	
	Backlog Size	%	No. of Overdue tasks / No. of received tasks	
	Quality of Execution (Rework)	%	Percentage of maintenance work requiring rework	<3%

Table 2.5 Common lagging indicators (25)

Category	Measures/ Indicators	Units	Description
Measures of Equipment Performance	No. of Failures	No.	No. of Failures classified by their consequences: Operational, Non-Operational, Safety etc
	Failure / Breakdown Frequency	No. / Unit Time	No. of failures per unit time (A measure of Reliability)
	MTBF	Hours	Mean Time Between Failures (A measure of Reliability)
	Availability	%	MTBF/(MTBF + MTTR) = Uptime / (Uptime + Downtime)
	OEE	%	Availability x Quality Rate x Performance Rate
Measures of Cost Performance	Direct Maintenance Cost	R	Total Corrective and Preventive Maintenance Cost
	Breakdown Severity	%	Breakdown Cost / Direct Maintenance Cost
	Maintenance Intensity	R / Unit Production	% of Maintenance Cost per Unit of Products produced in a period
	% Maintenance Cost component over manufacturing cost	%	% Maintenance Cost / Total Manufacturing Cost
	ERV (Equipment Replacement Value	%	Maintenance Cost / New Condition Value
	Maintenance Stock Turnover	No.	Ratio of cost of materials used from stock within a certain period
	Percentage Cost of Personnel	%	Staff Cost / Total Maintenance Cost
	Percentage Cost of subcontractors	%	Expenditure of Subcontracting / Total Maintenance Cost
	Percentage Cost of Suppliers	%	Cost of Supplies / Total Maintenance Cost

The use of all the measures shown on Table 2.5 is in line with the quest for continuous improvement, which can only be attained through use of performance measures since these identify performance gaps and areas to focus on.

2.9.2 Overall Equipment Effectiveness

There is an array of performance indicators for TPM but the most critical one is OEE (Overall Equipment Effectiveness). (12).

OEE targets the minimization of losses and hence it not only incorporates Availability but also Performance rate and Quality rate. (24)

OEE = A x PR x Q (24)

Where A is the Availability of the machine, and is the proportion of the time that the machine is actually available out of the time that it should be available (24).

According to Eti et al. (8) and Campell et al. (4)

Availability = (Loading time – Down time)/ Loading time or (Uptime – Down Time) / Uptime. It is therefore, affected by breakdown losses, set up and adjustment losses and other down time effects.

Performance Rate = Output / Loading time (4). It is a measure of the actual output compared to the design output. It is affected by idling and minor stoppage losses, as well as reduced speed losses (4) (8).

Quality Rate = This is the percentage of good parts out of the total produced (24). It can also be referred to as the number of good products to the input used (4). This is sometimes referred to as the yield, and the key parameters to monitor are quality defect, start-up losses and rework losses.

The adage goes that you get what you measure. Rodrigues (3) states that TPM is a measure of overall equipment effectiveness (OEE). Nakajima (12) evaluates OEE as a combination of plant availability, quality and throughput. OEE is not limited to maintenance issues, but also gives an

overall and broader spectrum on issues that affect Productivity and hence supports the continuous improvement effort. Other key maintenance result indicators are the number of failures (N), mean time between failures (MTBF), and breakdown frequency (N/unit time).

OEE is generally considered world class if it is at least 85% implying that all the three parameters that define OEE will each be at least 94.7% (24).

2.9.3 Six big losses that impact TPM

Nakajima (12) identifies the following losses that are further categorized by Rodrigues (3) as having a major impact on OEE, and therefore requiring special focus and attention.

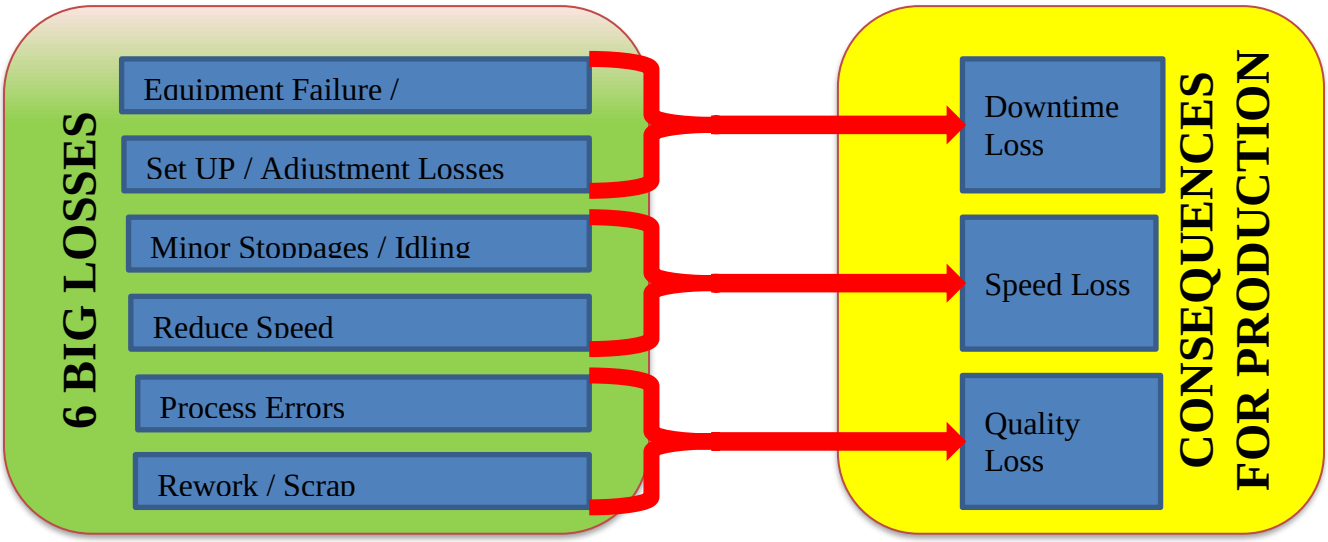


Figure 2.9 Six big losses (9; 3)

The categories are explained as follows:

Equipment Failure / Breakdown losses: These are time failures that are due to sporadic and / or chronic failures (4) (8) (9). Such failures result in output decline and occurrence of defects. Sporadic refers to unpredictable failure of unrelated parts of the machine without a pattern and chronic failure is when a single part/system fails all the time as a weak part of the equipment. They affect plant availability.

Set Up / Adjustment losses: This refers to the time after the production of one product, through to change over until a quality product is being produced for the next production schedule (4) (8) (9). This also affects plant availability.

Minor / Idling losses: These are stoppages that are caused by minor stoppages or minor malfunctions or just idling of machines (4) (8) (9). These are speed losses that affect throughput.

Reduced Speed losses: These are losses that are brought about because the machine speed will be slow. They can be defined as (4) (8) (9):

- losses due to the fact that the running speed is less than the design speed.
- losses due to the fact that the design speed is inherently lower than the technological demands of the current scenario.

The reduced speed loss is particularly applicable in cases where standards will have to be compromised due to equipment aging or to neglected deterioration. In some instances, the machine design speed is never taken into cognizance because of past history. These losses affect speed and therefore throughput.

Process Errors: These are defined as time and volume losses that occur after a periodic repair, start up after suspension due to a shutdown or holiday, and start up after employee breaks (4) (8) (9). These losses affect quality.

Rework / Scrap: These are defined as losses that are brought about by production of defective products and time that is invested in reworking that product to a good quality product (4) (8) (9). These losses affect quality.

2.10 Causes of TPM failure

While there may be concerted efforts to ensure that TPM implementation will be a success, there is an array of impediments that lead to failure. Rodrigues (3) outlines some of the constraints as:

- Problems with purchase of replacement material, preventing the performance of planned maintenance,
- Budget cuts for the team involved with TPM without reasonable explanation,
- Incorrect dimensioning of the maintenance team to deal with the programmed activities,
- No follow-up on maintenance backlog,
- Non-availability of machines for maintenance on the planned date,
- Constant change in schedule,
- Non-systematic accomplishment of maintenance planning giving a feeling of non-credit to it,
- Lack of commitment on those that are supposed to support maintenance, and
- The feeling that maintenance team are "firemen extinguishing the fire".

2.11 Conclusion

This section dealt with the three types of maintenance approaches and how they evolved into TPM. The benefits of TPM were also explained and evidence was presented on how some companies that used TPM improved their operational systems. Maintenance prevention has become very important in the initial design of equipment. The adoption of the eight TPM pillars and the seven elements of the TPM wheel were shown to be a precursor to effective TPM implementation. OEE is also an important performance measure for TPM especially in the elimination of the six big losses. There are common causes for TPM failure which must be dealt with for any TPM implementation to be a success.

CHAPTER 3: CONGLOMERATE BACKGROUND

3.1 Overview of Conglomerate

The conglomerate is a leading African producer of a wide range of high quality steel products, with a global reach through its various operations around the world. While key facilities are based in Gauteng, other sites are in Australia, Italy, Zimbabwe, Ghana, Zambia and Namibia. The conglomerate has more than 7 000 employees and manufactures Rolled products, Grinding media, Cast products and Wire rod products. According to the company's bulletin, one of its foundries in Germiston, Gauteng, is among the largest in the southern hemisphere. The company has the largest scrap shredder in Africa.

3.2 Company Divisions

In Gauteng, the company has four manufacturing divisions which are Rolled products, Grinding media, Cast products and Wire rod products. The Scrap Processing division is also one of the supporting divisions. Engineering is headed by the Head of Engineering at Head Office and the following organogram shows the whole conglomerate structure as far as Engineering is concerned. The Engineering organogram is depicted in Figure 3.1.

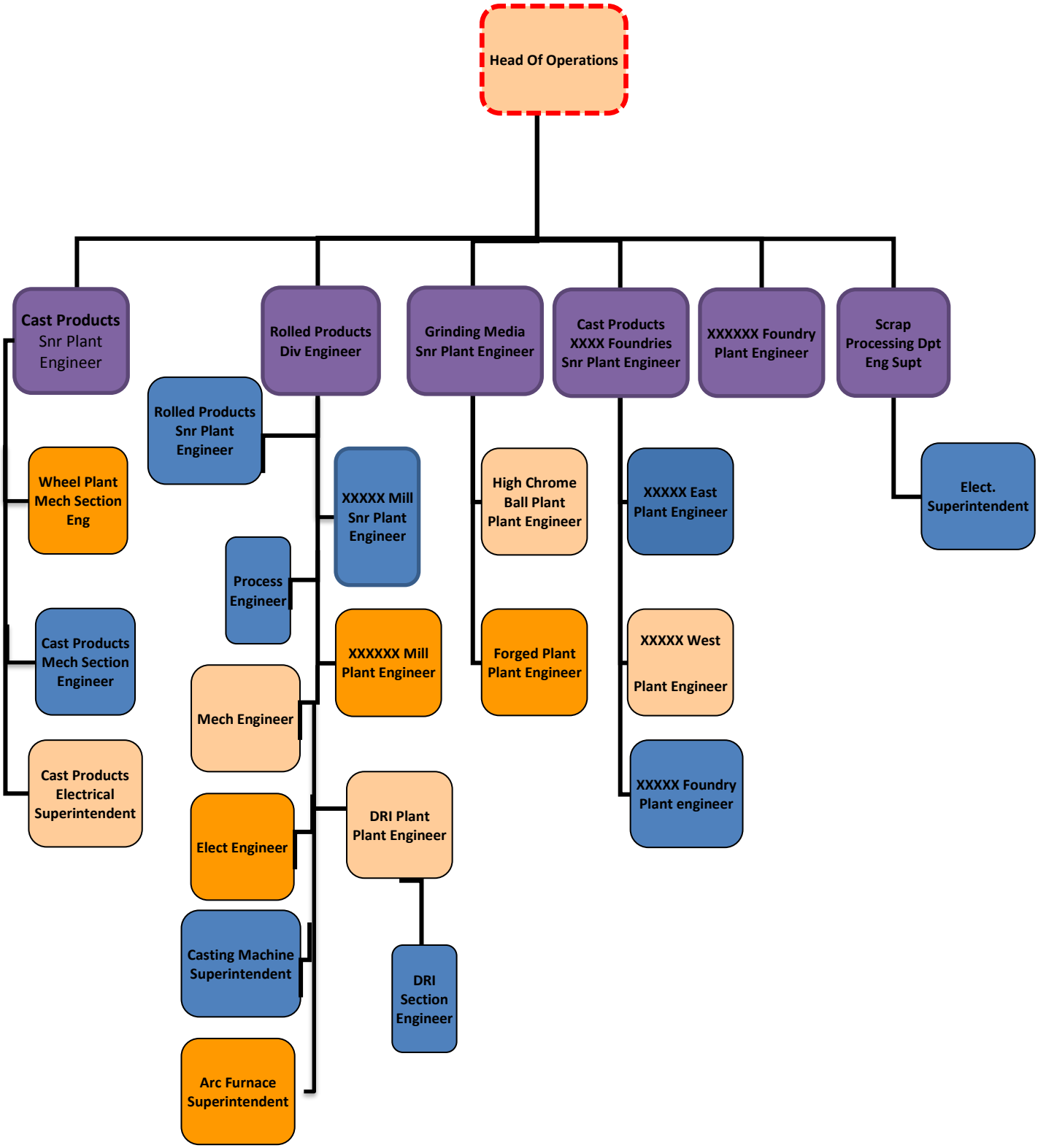


Figure 3.1 Engineering department organizational structure

The departmental structure of the organization is not unique in any way and is typically what one might find in any big conglomerate or manufacturing company.

3.3 Operational environment

Currently, the South African Steel Industry is facing challenges emanating from competition with cheaper steel suppliers especially from the Far East. The Conglomerate is facing challenges in the operating environment and has also been adversely affected by the strikes in the local mining industry which is a major customer for the conglomerate's products.

On a micro level, there is a clear realization that the company's maintenance strategy is not mitigating the negative impact of poor plant availability being recorded across various business units. While this research focused only on four business units, it has already been noted that the company's maintenance approach has to be revamped. The company has already engaged a consultant and is already in the initial stages of implementing an Uptime Improvement Project in order to standardize the maintenance approach.

The poor plant availability was negatively impacting product delivery and availability of the conglomerate's products. There currently is a shortage in supply of lifting chains and wire ropes for winches for instance, which is a critical product for deep sea oil drilling.

The South African Government, through the IDC, has also injected capital into the company and various improvement and expansion projects are in progress.

The chain making business unit is in the process of acquiring new plant and machinery for its expansion and retooling. These machines are the latest generation with the latest automation technology including robotics. The wire strand business unit has also expanded its pickling plant and a plant upgrade on process automation is in progress. The introduction of this new equipment must be met with an effective maintenance strategy to guarantee sustained performance and long asset life.

Four business units were assessed in this study and the following sections explain each of the business units' critical activities. It also explains in a minimal detail the operating environment of each business unit.

3.3.1 Business Unit A

This unit consists of the chain making plant. Wire is received from an external local supplier and some is received from China and comes in rolled coils of various diameters. The wire is cleared of rust by acid cleaning in the pickling plant. It is then delivered to machines that will it turn into a chain. The chain making process entails straightening the wire and cutting it into small pieces that will make the chain link. The cut pieces are bent and interlinked then welded by an electro-welding process. The two ends of wire fuse into each other and the strength of the fused joint determines the strength of the link.

Further treatment such as tempering and hardening is carried out in specially constructed pit furnaces where high grade chains with higher strength and durability are also made. Some chains may require special painting to meet special customer requirements.

This company exports chain all over the world where it is used in special applications such as lifting and rigging in the deep seas, as well as in offshore oil drilling.

The manufacturing plant equipment has a lot of moving parts consisting of cams, rollers, arms and push fingers in the case of the chain making machines. Currently, the plant has forty four (44) machines in use. The plant operates six days a week but market demands sometimes require that the machines are operated every day. The operating environment is noisy and dusty. The dust consists of metal particles. Fires due to electric arcing have also been experienced if the electric panels are not regularly cleaned. The whole process is very specialized and requires continual maintenance.

The unit was running on a breakdown maintenance basis at the time of the research. The maintenance costs were high because of the nature of the frequent breakdowns which in most cases were catastrophic failures.

The machines were commissioned more than thirty (30) years ago and documentation was very difficult to find. Machine overhauls were done with the replacement parts being made only when an old sample was available.

3.3.2 Business Unit B

This business unit produces wire products such as galvanized wire, mesh fencing, barbed wire and wire for cable armoring. The wire is received as rolled coils of rods and this is extruded to smaller diameters using wire drawing machines.

The plant has an acid pickling plant where the rolled wire is cleaned in sulphuric acid. The wire goes through various stages of finishing including galvanized in the galvanizing plant.

Unit B also faces stiff competition from imports. Operational costs have also escalated because of the negative impact of exchange rates. This has made it very expensive to import electrical spares. The unit is making mechanical components locally using local suppliers or machinists who are competent enough to fabricate the components. Labour has also been streamlined and the company has sacrificed the position of a Maintenance Planner replacing this function with a Maintenance Administrator.

Most of the equipment is at least thirty-five (35) years old and the equipment was last upgraded some ten (10) years ago. The plant operates at full capacity so windows for maintenance have to be scheduled in line with plant stoppages. Maintenance can only be done when there is no production. Emphasis has been placed on inspections and the annual plant shutdown that is done in December during the festive period. These challenges need to be countered to produce products at a reasonable cost and high overall equipment effectiveness. High plant availability is required to meet customer requirements and the plant was struggling to meet demand at the time of the research.

3.3.3 Business Unit C

This business unit was established in 1921 supplying wire ropes for hoists, to the gold and mining industry of South Africa. It also supplies wire ropes for anchorage to the off-shore industries. The unit prides itself as a world leading specialist in the manufacture of wire and rope solutions across a wide range of industries, especially ultra-depth mining shafts. Ultra-depth means any mining depth of three thousand metres (3,000m) and further below. Steel wire rope products are renowned for extra strength, extended fatigue performance and improved rotational resistance. This is a specialized environment where failure may result in serious accidents and fatalities.

The process flow for this business unit starts with the reception of patented galvanized wire rod. The rod is then drawn to the required thickness by the wire drawing machine. The drawn wire is then wound on spools to the required length. Thereafter the wires undergo a process of stranding. Stranding is the combination of individual wires to form a rope. The rope is then closed and wound onto a drum for dispatch.

Operating expenditure for capital expenditure and maintenance is very limited. As a result, process control is lagging behind competition due to inadequate investment especially in the areas of patenting and galvanizing. According to the Engineering Manager of the unit, 70-80% of PLCs and VFD technology is now obsolete and is no longer supported by suppliers. Some of the ranges of this equipment were discontinued around 2010. Technical skills, especially trouble shooting skills are poor. Availability of spares remain a challenge and new equipment that is being bought is also coming without drawings, which complicates maintenance problems.

3.3.4 Business Unit D

This business unit supplies sinter to blast furnaces. Sinter is a product mix used to enhance the extraction of iron.

Sinter production consists of stacking layers of raw materials into a huge pile using an Auto Stacker machine. The pile is then mixed using a Reclaimer and sent for Sintering in ovens through an array of conveyors, chutes and storage bins. The hot sinter is cooled in an After-cooler and crushed and thereafter, conveyed to the blast furnace section for storage or direct use.

The plant uses an Enterprise Resource Planning (ERP) system called SAP, and the Planned Maintenance module and six week shutdowns are held for the sinter plant. This is done based on past experience and mainly to replace worn out sections that would have been affected by high abrasion from sinter.

The plant faces challenges of limited budget to upgrade equipment and replace obsolete automation equipment. According to the Maintenance Engineer, contractors are getting more and more expensive to execute the shutdowns, and cost of spares and equipment is getting higher and higher.

Historically, changes and modifications were being effected to plant without any updates on the technical drawings. As a result, there are no accurate technical drawings available to assist Plant Maintenance management.

3.4 Conclusion

The four business units face an array of challenges in a difficult operating environment. This investigation was useful in assessing the effort required to achieve alignment for the maintenance system to the requirements of an effective maintenance program such as TPM to be implemented with success.

CHAPTER 4: THEORETICAL FRAMEWORK APPROACH

4.1 Framework Explanation

According to Panneerselvam (27), a model supported by appropriate literature and data assists in solving real life problems. Therefore, for any research, a theoretical frame work is necessary to provide a clear direction that the research will follow.

This research used the theoretical framework depicted in Figure 4.1.

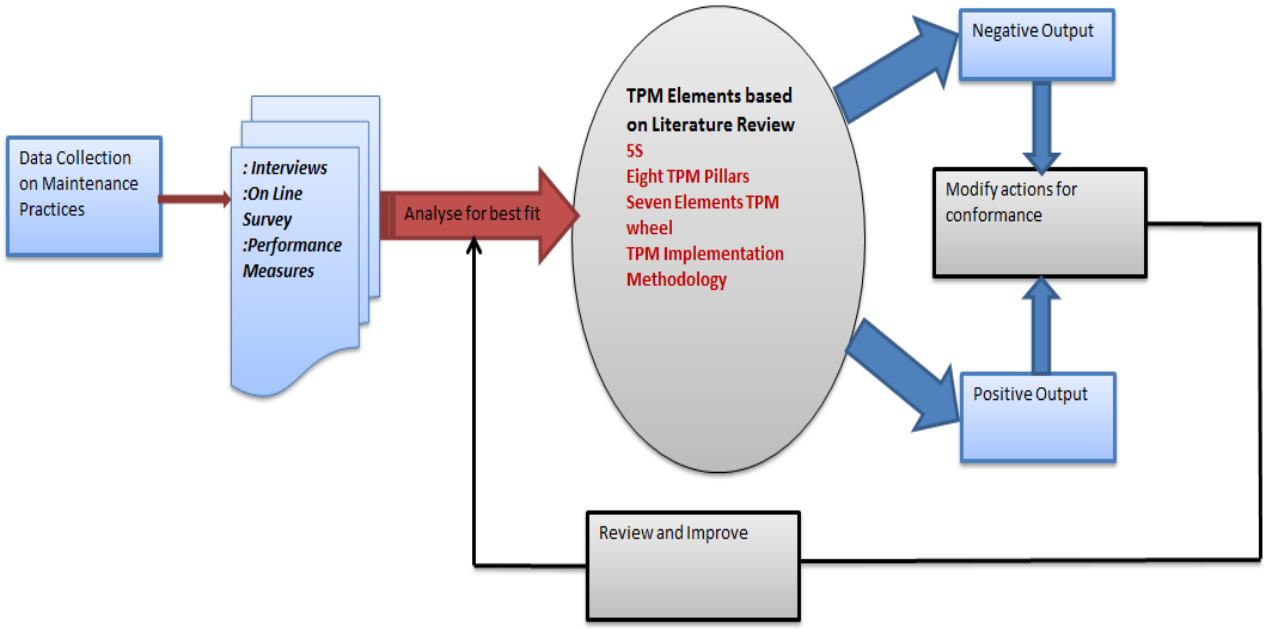


Figure 4.1 Theoretical Framework for the research

The TPM elements derived from the literature review were used as a framework for this research. 5S was chosen because it is the foundation that supports the eight TPM pillars. Adoption of 5S from the early stage already aligns some maintenance practices to TPM. When the pillars form part of the maintenance practices, and the seven elements of the TPM wheel become part of daily maintenance practice, then such an organization can be regarded as having maintenance practices that are already aligned to TPM implementation.

CHAPTER 5: RESEARCH METHODOLOGY

This chapter explains the research methodology focusing on the type of research method used, sampling and data collection procedures employed, and analysis plan and ethical considerations used in the study.

5.1 Types of Research Used

Research is known to be either quantitative or qualitative in nature (27) (28). Quantitative research optimizes a distinct measure of performance of a system being studied. It generates numerical data that can be used to generate useable statistics. It is used to quantify attitudes, opinions and behaviors. Qualitative research however, aims to test the significance of a hypothesis of a study. It is used to identify underlying reasons, opinions and motivations. It provides insights into problems and helps to develop ideas that can be further used in quantitative research. This research employed a combination of both qualitative and quantitative research paradigms. It was qualitative since maintenance behaviors, opinions and practices cannot be empirically quantified and quantitative because empirical values were given through analysis of the performance measures, both lagging and leading indicators.

5.2 Research Approach

The framework explained in Chapter 3 was combined with a methodology structure resulting in the three stage method in figure 5.1.

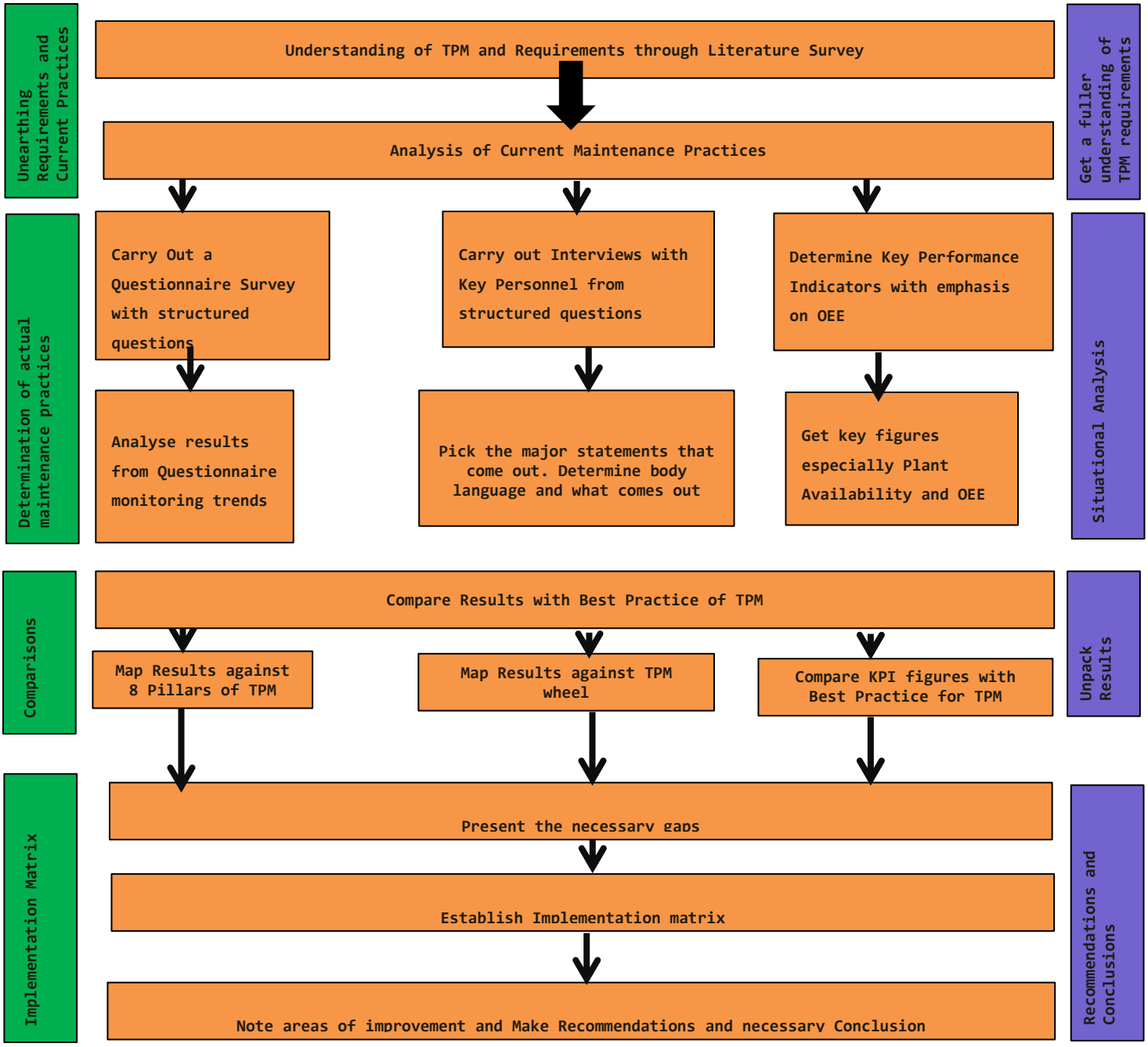


Figure 5.1 Research approach

The three-stage matrix on Figure 5.1 was used as an exploratory tool and is explained in the following detailed data collection section.

5.3 Data Collection

Three ways were used to gather data. These were an online survey, actual performance measures and interviews. The data gathering was focused on the four targeted business units since they had been identified to be more willing to give information and partake on the survey during the inception of the research when authority was sought. It became easier to target personnel in the four business units. They formed part of the core sample for this research.

The online survey was structured in a way that it solicited information on how TPM was understood by the personnel from the four business units. The online survey had statements that the respondents had to rate in terms of how they practiced maintenance in their day to day activities. The responses gave an indication of how such practices tied to TPM requirements or not.

The Head of Engineering and personnel from the four business units also participated in the interviews. The Head of Engineering was in the process of embarking on a new project that had focus on uptime improvement and would affect the quality of maintenance for the company.

The performance measures were given from monthly reports. This was meant to determine the critical key performance figures, maintenance practices and how the various departments viewed their maintenance roles. This information was obtained from maintenance and other operational reports that were made available by respondents especially Engineers, in support of this research. Data collected and responses are in Appendices E1 and E2.

5.3.1 Online Survey

An online survey to determine the extent of respondents' maintenance understanding was conducted using survey monkey, a web based application. The survey was administered on departments of production, maintenance and support functions of safety and quality. An e-mail with the link to the questionnaire was sent to respondents in the four selected business units. The questionnaire targeted Engineers, Superintendents, Production Managers, Operations Managers, Maintenance Foremen, Quality Controllers and Safety personnel. The survey questionnaire (Appendix B3) used likert scale closed questions and open ended questions. The success of a survey method depends on the strength of the questionnaire used (27). The likert scale questions

were used to establish perceptions about maintenance practices. The open ended questions were important in order to get the views of the respondents and capture common themes without imposing restrictions.

As already seen from the Literature Survey, a questionnaire is a set of well formulated questions meant to probe and obtain responses from respondents. (27). The following steps were used to design the questionnaire.

1. Identification of relevant TPM issues that any organization must align with.
2. Formulation of a set of questions relevant to each particular issue by deciding on the content and format of each question.
3. Rewording questions to remove ambiguity.
4. Formatting and appropriate sequencing of the questionnaire to ensure smooth flowing of responses and keeping the respondents engaged.
5. Piloting the questionnaire by pre-testing with peers in the company.
6. Reviewing pre-testing feedback to the questionnaire and making improvements.
7. Loading questionnaire on the survey monkey platform.

5.3.2 Detailed On Line Questionnaire Structure

The following sections dealt with how the questions on the online survey were structured. As already explained in the Literature survey, TPM has critical elements that need to be present in order to ensure alignment with maintenance practices. These are the eight pillars of TPM, the 5S, the TPM wheel and management of the six big losses. The questions for the online survey were structured around identifying if the attributes necessary for the critical elements were already in practice.

Demographic Data: This section generally looked at the profile of the respondents and the nature of the operations as well as the size of the business section. This information was important in order to ensure representativeness of respondents. The nature and size of a business unit also gave an indication of the span of control for a particular respondent and such information would generally indicate the extent of influence of the particular respondent.

Understanding of TPM and AM: In this section all questions were structured around a full package of the requirements of TPM and were meant to gauge the understanding of the respondents and their views on TPM. Another set of questions was also asked on participants' understanding of Autonomous Maintenance since it is an integral part of TPM. This set of questions also linked with an exploration of the two TPM pillars namely; Autonomous Maintenance as well as Training and Education.

A likert scale was used for the responses with the key options:

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Maintenance Practices in Place: This section was the most critical one since it looked at the current practices at the various business units and how they were perceived by the various respondents. The questions were structured into four main areas of focus and these were Leadership and Direction, Planned Maintenance, Maintenance Administration and Reliability Improvement. The study was meant to explore the alignment of these focus areas to the pillars of TPM namely:

Leadership and Direction – This would explore Focused Improvement, Early Equipment Management pillars.

Planned Maintenance – This would explore the PM pillar.

Maintenance Administration – This would explore Office TPM, Quality, Maintenance and SHE pillars.

Reliability Improvement – This would explore the Focused Improvement and Quality Maintenance pillars.

The data gathered was important since it formed the basis for the investigation into the alignment of such practices to possible implementation of TPM. Forty one statements were subjected to a slightly adjusted likert scale. The word "neutral" is replaced by "uncertain." The data gathered in this section revealed the gap between an ideal situation of a company whose practices are aligned to TPM implementation and one which is acting contrary to TPM requirements.

Responses to Open Ended Questions: This measured the maturity level of the various business units through the operational environment. It looked at soft maintenance practices and delegations of authority and measured how important certain values were to the overall company's maintenance ethos. It was also a review of the maintenance environment on the basis of the foundations on which TPM practices are built. There was a section where respondents were required to make their own statements regarding what they felt about the maintenance practices and some statements had common themes that required further attention.

5.3.3 Interviews

Interviews were conducted with selected personnel based on availability, seniority and relevance to the maintenance practices using a template in Appendix D1. The interviews were administered on ten respondents from Operations and Engineering, particularly those in Maintenance and Process Engineering. The specific respondents interviewed were:

A1 - Maintenance Foreman
A2 – Electrical Foreman
A3 – Maintenance Foreman
A4 – Engineering Manager
A5 – Mechanical Engineer
A6 - Maintenance Engineer
A7 - Maintenance Planner
A8 - Head of Engineering
A9 – Engineering Services Manager

The responses were recorded and transcribed for analysis. The interview questions probed the maintenance practices in place and emphasized on the challenges faced by each respondent in effective execution of maintenance. The specific interview transcripts are attached as appendix D2.

According to Oxford Dictionary (28), an interview is an interaction between people where questions are asked and answers are given. The interviewer asks questions and the interviewee gives the answers. The interview's main objective is to collect relevant information depending on the intended use. The structure of the interview can be formal or informal. McNammara,(42) note that, an interview is useful for getting the story behind a participant's experience and pursuance of in depth information around a particular topic. Its purpose is to explore the views, experiences, beliefs and / or motivations of individuals on specific matters. It is also a useful follow up to get more information on certain respondents.

The questions for the interview probed the maintenance practices that were being carried out on the four business units in the conglomerate. A test for the interviews was done on ten people, five people were employed by the conglomerate being studied while the other five worked in other companies and were known to the interviewer. Their comments formed the basis of the interview questions' revision. Appointments for the interviews were made with targeted members of the departments after getting prior authorization to carry out the research as per the letter in Appendix A.

The interviews were carried out in the following five stages as recommended by Panneerselvam (27):

1. Rapport Building: This was the part where the interviewee's buy in was solicited prior to carrying out the interview. Assurances were made that information was confidential and would not be used for victimization or in any way that would negatively affect the career and standing of the respondents and that their opinions were valued. The respondents were told of the estimated duration of the interview which was basically 30 minutes per person. Nine interviews were carried out.

2. Introduction: This was done during the commencement of one on one interviews. The respondents were told of the purpose of the study and given assurance that the interviews had been authorized by the company hierarchy. This was done through providing the authorization letters (See Appendix A). The reason was to ensure that a fuller picture of the current maintenance practices was freely told by the respondents without fear of victimization.
3. Probing: The interviewer had to ask probing questions and encourage the respondents to answer fully and freely. There was the use of gestures to ensure continued interest in the interview flow. Meanwhile notes on key words and phrases were also made in order to come up with a thread on what story the interviewees were giving. This was the stage where interviewees were explaining freely their thoughts on TPM, the company's industrial climate, their fears and expectations whenever TPM was to be introduced.
4. Closing: This stage was for thanking the respondent for the time spent and emphasizing the guarantees of confidentiality.

5.3.4 Performance Measures

Performance Measures were depicted based on a particular business' engineering report and production report. The reports submitted already had calculated data especially those dealing with OEE and Plant Availability. The performance measures given by the respondents were then compared with those proposed by Muchiri (25) in his routine work management process matrix. Special emphasis was placed on whether OEE was being monitored. Focus on continuous improvement of performance was also determined through maintenance initiatives.

5.3.5 Analysis for Best Fit

For the analysis for best fit, key elements derived from the maintenance practices were juxtaposed against the expectations of TPM in order to determine the presence of a match or mismatch. Basic practices such as the availability of a PM program, the use of performance measures such as OEE, and the words spoken by respondents were compared against the ideal situation for TPM prevalence. This was compared with best practice as discussed in the Literature review.

Where it was deemed that the maintenance practices were not in tandem with TPM on a specific theme or pillar, strategies would be recommended to ensure a positive culture for TPM was promoted. This would apply to pillars such as AM where operators would be expected to carry out simple tasks such as lubrication of their equipment. In the case where maintenance practices were aligned to TPM, these were reinforced and encouraged for sustainability.

The results of the interviews, on-line survey, key performance indicators and observations were compared with the requirements of TPM in order to check on alignment.

5.4 Ethical Considerations

In research, ethical principles govern the behaviour of the researcher before, during and after data collection. This section explains the ethical considerations applied in this study.

5.4.1 Seeking Permission and Authority

Permission was sought from relevant authorities. This was done in line with the requirements of the University of Witwatersrand regarding research that involves interaction with people. An Ethical clearance number MIAEC 072/15 was granted by the University. Authority to carry out the research was requested with top management of the conglomerate (See letters in Appendix A). This was granted through a letter (Appendix A1) that gave the authorization to carry out the research.

5.4.2 Informed Consent

Informed consent was based on potential respondents' understanding of the principles of voluntary participation, freedom to withdraw at any given stage of the research, and the purpose of the research. In this research, especially during collection of qualitative data, the first step was to disclose my identity and explain the purpose of the study ensuring that research procedures are fully understood. This was followed by request for consent from the participant.

5.4.3 No Harm to Participants

The researcher ensured that respondents were not distressed by avoiding sensitive, potentially harmful and embarrassing questions.

5.4.4 Confidentiality and anonymity

Information that was used in this research was considered privileged and confidential as agreed by the company before embarking on this research. This was supported by a Letter from the Training Manager (See Appendix A2). As such, the name of the specific conglomerate that was investigated remained anonymous. Names of the respondents and financial information considered out of the public domain were not revealed. However, this did not compromise the quality and context of the data that was gathered for this research.

5.5 Validity and Reliability

The data used in the research was collected through both quantitative and qualitative approaches. In order to ensure that the research passed the reliability test, meaning that the results obtained were replicable and also to ensure that the research was valid, meaning the means of measurement was accurate and measuring appropriately, a triangulation approach was used in the research. The data gathered showed consistency in the responses that came from the on line survey, interviews and performance measures reports.

5.6 Data analysis

The results from the Performance measures, Interviews and On line responses were analysed using gap analysis in order to determine TPM pillars and TPM wheel elements that were richly addressed and those that were poorly addressed through the maintenance practices. This revealed if the maintenance practices were aligned or not.

CHAPTER 6: RESULTS

6.1 Introduction

The chapter discusses results based on the three main approaches used and their implications to TPM.

6.2 Current Maintenance Practices based on Measured Parameters

Four business units gave samples of monthly reports of what they measured. These monthly reports are presented as they are. More of the same reports is also given in the appendices.

6.2.1 Plant A Measurements

The Chain Making Plant referred to as Plant A, had its performance measures submitted by the Production Manager. The plant consists of 44 machines that are used in the production of chain. In order to determine the performance of this plant, the duration of downtime caused by breakdowns was recorded. The maintenance fitter recorded the time taken to restore the machine to an operable state after repairs and this is referred to as downtime as already explained in the Literature review section. The maintenance foreman would capture the particular machine line number, the fitter who would have done the job, the date, and duration of the downtime in hours and minutes. At the end of the month, the data would be collated having noted downtime of each machine and summing up the total downtime durations. The top ten machines with the highest downtimes would be selected and investigated to rectify the major reasons for such breakdowns. This was done by the foreman and the engineer. Emphasis was placed on tracking and reducing the downtime with the ultimate goal of having zero breakdowns. The breakdown duration was analysed as an absolute figure and not as a percentage.

The data was depicted on a graph and a typical graph is shown on Figure 6.2 below. This monitoring of the machines helped in identifying and rectifying the problem areas before their escalation into catastrophic failures.

Table 6.1 List of breakdowns for June 2014

LINE	Total down time	DATE	SHIFT	DESCRIPTION	FITTER ATTEND	HOURS	COMMENTS
1	15	06.06.14	Night	Feed grip	Jannie	1	Bleed booster
		12.06.14	Day	Mandrel block	Ray	1.5	Fit new mandrel
		17.06.14	Day	Mandrel block	Leon	2	Adjust settings
		20.06.14	Night	Mandrel block	Mavuso	3	Fit shims to mandrel
		20.06.14	Night	Feed lever	Chris	7.5	Machine brass block to adjust stroke
2	15	09.06.14	Day	Copper slide 1st head	Tumi	3	Replace roller pin
		09.06.14	Night	Former main cam	Godfry	1	Tighten bearing caps
		12.06.14	Day	Embosser	Rampou	1	Weld pins on head
		24.06.14	Day	Service	Tumi	10	Service water and air
3	4.5	03.06.14	Day	Twister spindle	Godfry	4.5	Repair rack
4	0						
5	19	02.06.14	Night	Welding lever 1st H/F	Rampou	9	Fit new Bushes
		04.06.14	Day	Welding lever	Ray	4.5	Replace wear plate
		09.06.14	Day	Water system	Ray	2	Repair water leak
		12.06.14	Day	Copper slide 1st head	Tumi	2	Fit wear plate and roller
		23.06.14	Day	Feed grip	Mavuso	0.5	Bleed system
		24.06.14	Day	Straightening roller	Rampou	1	Repair keeper plate
6	10	03.06.14	Night	Welder clutch	Rampou	1	Repair air pipe
		03.06.14	Day	Feed grip	David	1	Replace o rings on grip block
		05.06.14	Day	Proof loader	Mavuso	1	Repair key on drive
		17.06.14	Day	Coppers 2nd head	Klaas	2	Repair water leak
		23.06.14	day	Proof loader	Tumi	1.5	Adjust chain on drive
		23.06.14	Night	Proof loader	Godfry	3.5	Replace broken chain

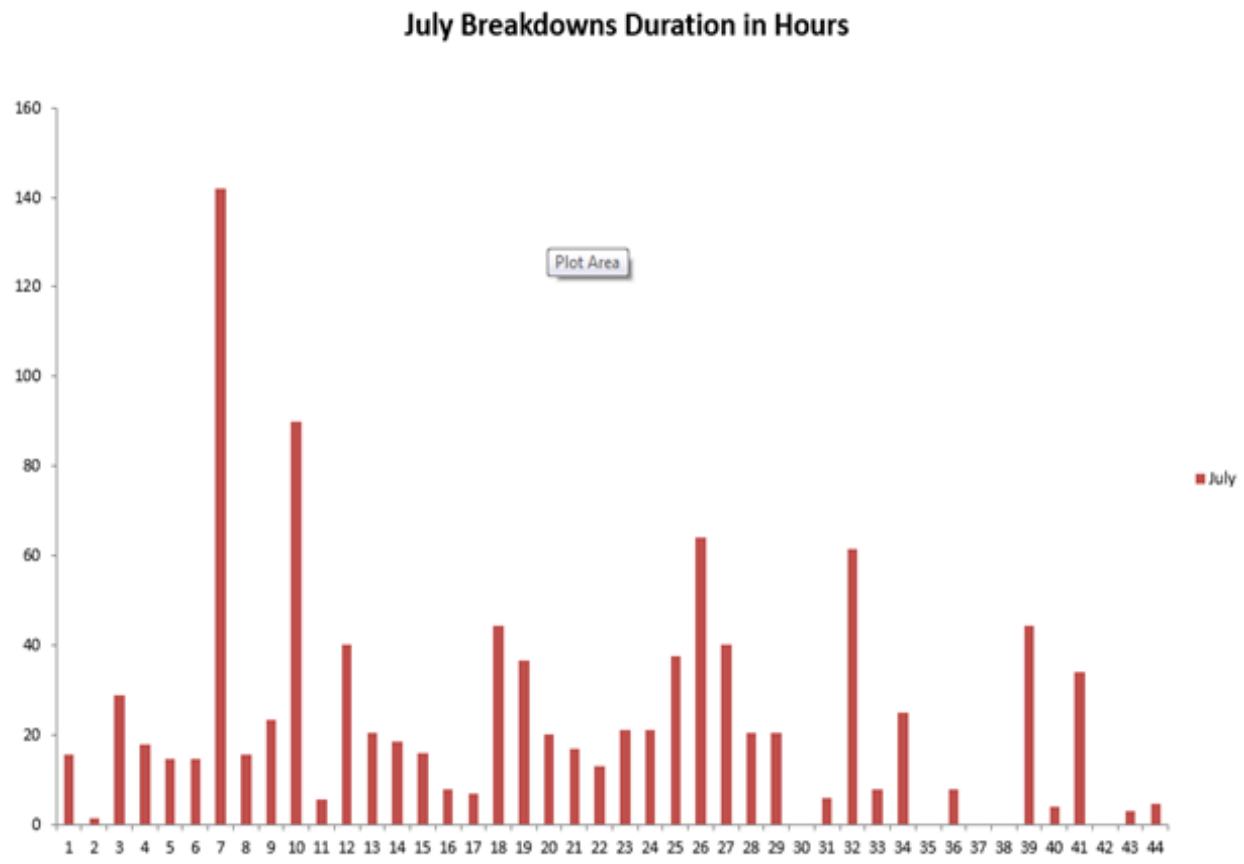


Figure 6.1 July breakdowns duration for plant A

The daily breakdown reports were also further analysed by the operations manager who combined this with the production output and quality figures to come up with an OEE graph on Figure 6.3. These graphs were in excel format in a workbook file that was continuously being updated as and when required.

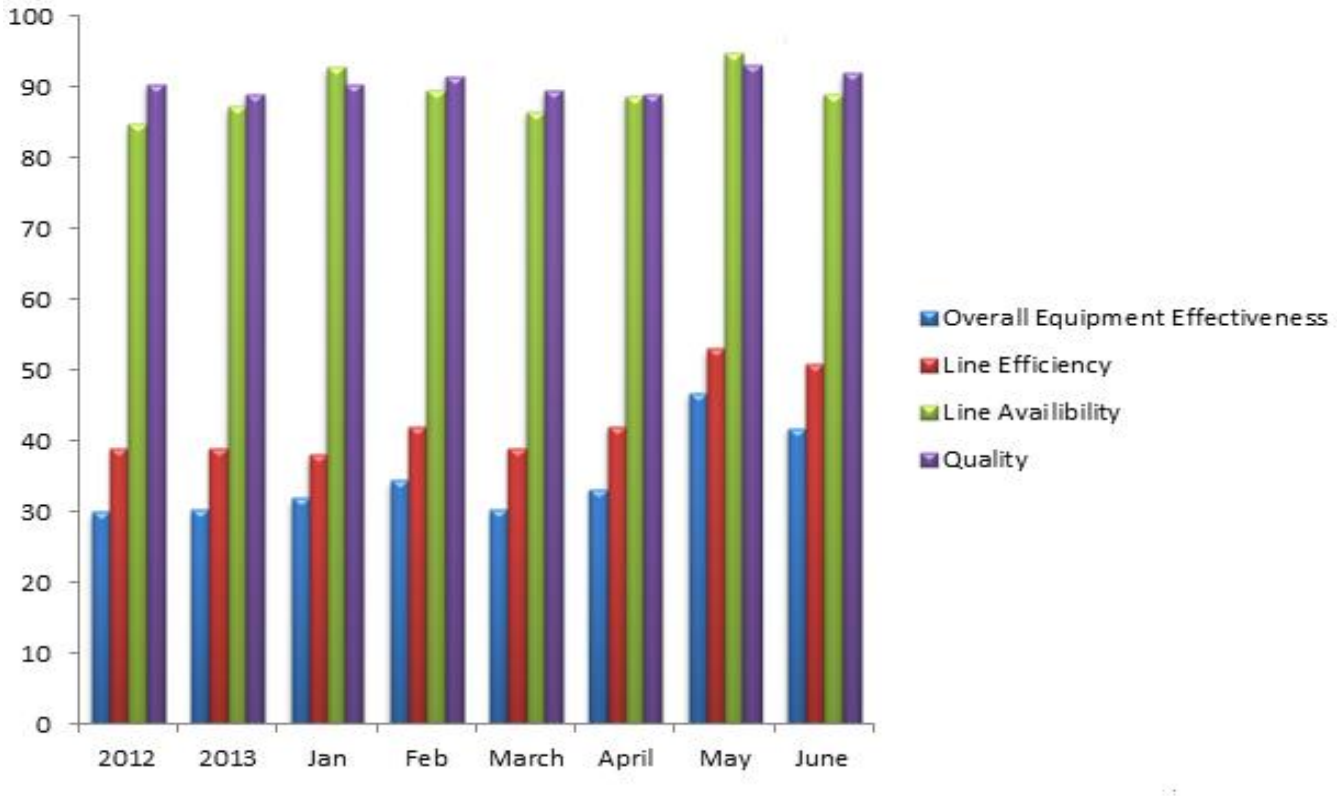


Figure 6.2 Performance statistics for plant A

Definition of Terms Used

Line Efficiency - Actual Production Output/ Expected Production Output. This is in line with the definition given in the literature review. The actual production was based on the quantities that were produced during the particular period while the expected production output was based on the known design rate of production multiplied by the period duration.

Line Availability - Uptime / Total Available Time. The uptime is the time that the machine would be up and running while the available time is the time that the equipment is in such a physical state that it would be ready for production.

Quality - 100% - Scrap Rate

OEE - Line Availability x Line Efficiency x Quality

The above four indicators were the only ones that the plant was monitoring and measuring.

Taking the month of June for example, the OEE consisted of the following values:

Line Efficiency = 50%

Line Availability = 90%

Quality = 95%

OEE = Line Availability x Line Efficiency x Quality

= 0.5x0.90x0.95 = 0.428 =42.8%

This OEE value is way below the world class OEE of 85%.

This business unit had a low OEE of less than 50% overall. As already discussed in the literature review section, the three parameters that make up OEE have a strong bearing on the overall value. However, it is mathematically clear that Line Efficiency had a negative effect on OEE by lowering it further down. As long as the line efficiency is this low, the OEE of the plant will remain poor.

The alignment of maintenance practices to TPM has the measurement and improvement of OEE as a yard stick. In this case OEE has been lower than world class standard. The line efficiency was so low that 50% line efficiency was considered as an achievement.

6.2.2 Plant B Performance Measurement

The unit produced wire for fencing and manufacturing of armor cable. As such the plant consisted mainly wire drawing machines meant to reduce rod wire to specific smaller diameters through cold drawing. The analysis of plant performance measures was carried out by the maintenance engineer. Daily trending of breakdowns was used to monitor performance and a typical report is depicted in Table 6.2.

Table 6.2 Typical trending of breakdowns for Plant

LOST TIMES - ENGINEERING

DATE	MECHANICAL	ELECTRICAL		Available Time	Galv Prod	W/Draw prod
2014/08/01	175	789		24	201	203
2014/08/02						
2014/08/03						
2014/08/04	144	46		24	163	205
2014/08/05	225	0		24	182	242
2014/08/06	50	90		24	220	239
2014/08/07	0	0		24	219	244
2014/08/08	21	7		24	218	267
2014/08/09						
2014/08/10						
2014/08/11	232	250		24	91	205
2014/08/12	227	308		24	226	223
2014/08/13	15	115		24	266	264
2014/08/14	145	0		24	268	273
2014/08/15	28	0		24	286	253
2014/08/16	95	150		24	261	265
2014/08/17	30	80		24	256	227
2014/08/18	49	0		24	241	238
2014/08/19	31	47		24	232	244
2014/08/20	299	201		24	254	234
2014/08/21	134	24		24	242	261
2014/08/22	106	364		24	230	246
2014/08/23	441	387		24	257	249
2014/08/24	20	208		24	240	280
2014/08/25	40	10		24	211	257
2014/08/26	0	50		24	219	251
2014/08/27	250	105		24	228	254
2014/08/28	51	96		24	260	253
2014/08/29	40	26		24	279	221
2014/08/30	346	182		24	265	241
2014/08/31	102	396		24	260	267
	3296	3931	0	648	6275	6606
Total hours	54.93	65.52				
Total eng		120.45		7776		
Days Run		27				
Percentage availabity		98.45%				

The daily downtimes for mechanical and electrical sections were noted daily and were recorded in minutes. At the end of the month they were added up and converted to hours. The depicted available time per day was 24hrs since this was a 24hr operation covered through a shift system. The total downtime was compared to the total available hours in order to calculate the Plant availability.

In Table 6.2, the plant availability for the month was 98.45%.

For a monthly report of this plant, see Appendix E1

6.2.3 Plant C Performance Measurement

The third plant that also availed data was the Rope Wire Products also referred to as Plant C. The plant was divided into the Ropery division and Wire drawing division. The Ropery division had 19 machines that were uniquely identified, whose performance was monitored through downtime monitoring. Table 6.3 is an example of this weekly record.

Table 6.3 Weekly trending downtime on 19 machines of Ropery division

15/02/2016	WEEK 07					
MACHINE	TOTAL HOURS IN A WEEK(hrs)	TOTAL DOWN TIME(hrs)	AVAILABLE TIME(hrs)	RUN TIME (hrs)	AVAILABILITY	MACHINE EFFICIENCY (%)
A19	78	17.1	60.90		78%	
A28	78	15.6	62.40		80%	
B21	78	2.7	75.27	8.68	96%	12%
B22	78	2.3	75.75	26.62	97%	35%
B23	78	1.5	76.53	30.68	98%	40%
B24	78	3.4	74.58	24.15	96%	32%
B25	78	3.6	74.38	13.7	95%	18%
B27	78	8.0	70.00		90%	
B30	78	11.3	66.70		86%	
B31	78	0.0	78.00	0	100%	0%
B33	78	0.3	77.67		100%	
B34	78	13.2	64.78		83%	
B35	78	0.8	77.25		99%	
B36	78	5.25	72.75		93%	
TC10	78	8.87	69.13		89%	
TC11	78	1.28	76.72		98%	
TC13	78	3.2	74.83		96%	
TC14	78	12.9	65.08		83%	
RP-01	78	0.4	77.60		99%	
TOTAL	1482	111.67			92%	

Further analysis was also carried out by analysing the Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) for each particular machine. Table 6.4 shows the measured weekly trends and the subsequent graphs that also come out of the data.

Table 6.4 Weekly MTBF and MTTR for each machine

WEEKS	2		3		4		5		6		7		8		9		10	
	MTBF(hrs)	MTTR(hrs	MTBF(hrs)	MTTR(hrs	MTBF(hrs)	MTTR(hrs)	MTBF(hrs)	MTTR(hrs)	MTBF(hrs)	MTTR(hrs)	MTBF(hrs)	MTTR(hrs)	MTBF(hrs)	MTTR(hrs)	MTBF(hrs)	MTTR(hrs)	MTBF(hrs)	MTTR(hrs)
A 19	7	1.22	25	0.8	9	1.82	72	6	8	0.7	8	2.13	15	4	6	1	10	0.88
A 28	25	0.87	26	0.35	12	1.05	12	1.02	78	0	6	1.57	4	1	38	1	10	1.22
B21	26	0.37	12	1.02	12	0.63	39	0.42	25	0.78	38	1.37	10	1	10	1	21	1
B22	78	0	0	0	78	0	26	0.42	9	0.83	25	0.75	14	2	78	0	9	0.17
B23	14	1.32	25	0.83	78	0	19	0.42	77	0.83	38	0.73	38	1	19	1	77	0.57
B24	38	1.4	6	0.87	12	0.67	9	0.68	77	1	75	3.42	75	3	6	3	8	3.02
B25	9	2.05	10	1.07	38	0.97	12	0.67	38	0.57	12	0.6	19	1	19	1	25	0.53
B27	10	0.85	19	0.88	36	3.25	78	0	39	0.45	0	0	12	1	34	5	7	5.08
B30	8	0.7	38	0.63	38	0.92	11	2.18	78	0	15	0.67	78	0	4	4	23	3.55
B31	78	0	78	78	78	0	78	0	39	0.33	0	0	78	0	78	0	7	0.72
B33	25	0.78	4	1.33	8	0.62	4	2.57	78	0	78	0.33	6	1	6	1	19	0.8
B34	9	0.83	12	1.03	6	1.38	10	0.73	23	0.71	11	2.2	13	2	7	4	38	3.75
B35	77	0.83	9	0.9	38	0.7	9	0.68	78	0	77	0.75	25	1	7	1	36	1.3
B36	78	0	19	0.4	10	0.82	25	1.47	78	0	15	1.05	78	0	19	1	18	0.75
RP01	77	1	8	1.53	14	1.2	12	0.9	36	2.52	78	0	25	1	25	1	78	0.68
TC10	38	0.57	78	0	78	0	39	0.47	78	0	39	0.43	39	1	37	2	77	1.72
TC11	39	0.9	38	0.62	19	0.75	78	0.00	38	0.72	38	0.65	78	0	9	4	78	4.03
TC13	78	0	78	0	78	0	78	0	38	0.97	37	1.58	78	0	78	0	77	0
TC14	39	0.33	26	0.42	14	1.25	39	0.25	23	3.27	8	1.62	77	1	35	4	78	4.47

The results were plotted onto a graph forming part of the weekly typical report Figure 6.3.

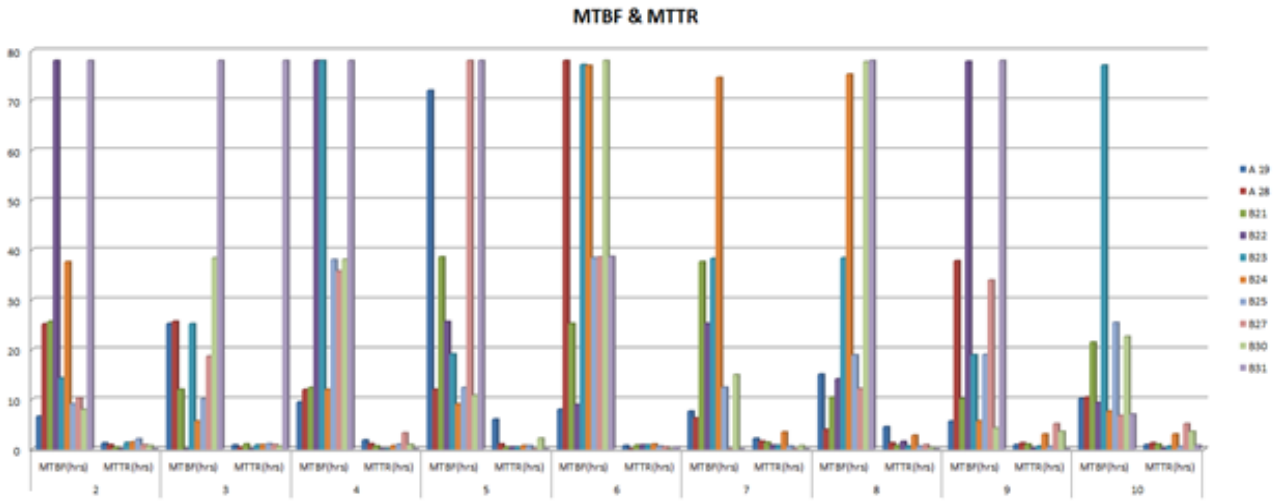


Figure 6.3 Weekly MTBF and MTTR graphs

The terms in use are defined as follows:

Available Time - The sum of planned machine hours in the calendar month based on planned shifts

Engineering Downtime - The sum total of all mechanical and electrical breakdowns that happen on the plant

Availability - Percentage of (1 – Engineering Downtime/Available Time)

Machine Efficiency - Actual Production based on actual production time / Expected Production based on the production time.

MTBF - Mean Time Between Failures is the statistical average of the time that it takes for a machine before a failure occurs in its entire life.

MTTR - Mean Time To Repair is the average time taken to restore a machine once it has failed.

Based on the available data for this section, it was clear that a lot of effort was being put into getting scientific information on the performance of this particular business unit. The approach of determining MTBF and MTTR showed that the plant aimed to improve on plant availability and focused on issues that were an impediment to good maintenance practices. This plant had a good performance measurement approach which was well detailed and meaningful.

6.2.4 Plant D Performance Measurements

Plant D data analysis is presented in matrix form as depicted in Table 6.5. This plant is used to produce sinter, a premix of fuel already combined with iron that is fed to the blast furnace in the production of pig iron. The plant is divided into A and B sections but for the purposes of measurement illustration, only section A is analysed.

Table 6.5 Typical performance measures for plant D (A section or Plant)

A Plant	Code	Jan	Feb	Mar	Apr	May
Calender time		44640	40320	44640	43200	44640
P Unused Available Time	P	0	0	0	0	0
U -Utilized Available time	U	44640	40320	44640	43200	44640
Q Planned Maintenance time	**Q2**	**7200**	**4320**	**2880**	**1440**	**0**
Gross Operational Time		37440	36000	41760	41760	44640
S External breakdown Time	S	0	0	0	0	0
Available Operational Time		37440	36000	41760	41760	44640
T1 Internal Production delays	T1	0	0	0	0	0
T2 Internal SIN Breakdowns	T2	64	988	1868	1068	3200
T3 Internal RMH breakdowns	T3	0	0	0	1	0
T4 Internal FMB Breakdown	T4	984	2068	0	0	0
T5 Development delay time	T5	0	0	0	0	254
Planned Maintenance Ratio	Q2	83.9%	89.3%	93.5%	96.7%	100.0%
S External Availability Ratio	S	100.0%	100.0%	100.0%	100.0%	100.0%
Sinter Maintenance Availability Ratio	T2,5	99.8%	97.3%	95.5%	97.4%	92.3%
RMH & FMB Maintenance Availability Ratio	T3,4	97.4%	94.3%	100.0%	100.0%	100.0%
Total Maintenance Availability Ratio	T2-5	97.2%	91.5%	95.5%	97.4%	92.3%
Available Time Ratio (AR)	Q,S,T	81.5%	81.7%	89.4%	94.2%	92.3%
Production Utilization Ratio (SR)	T1	100.0%	100.0%	100.0%	100.0%	100.0%
Total A Plant Availability (OEE)		**81.5%**	**81.7%**	**89.4%**	**94.2%**	**92.3%**

This plant collected a lot of detailed data for its analysis. It also measured OEE which was a good practice for TPM alignment in terms of performance measures.

6.3 Overview of Performance Measurement

The four business units that had performance measures provided enough evidence of a wide variety of measures that were in place. While all of them commendably had some measurement practice in place, the measures fell short of addressing the 8 TPM pillars especially the one of equipment and process improvement.

6.4 On line Survey Results

This section will show the results of the survey. 55 out of the 200 targeted employees for this survey participated. Respondents who participated in the survey were from the four business units. The score for the respondents on a particular question is shown on Tables 6.6 to 6.11.

6.4.1 Understanding of TPM

The section sought to determine whether the respondents understood the key elements of TPM. Table 6.6 below shows the statements as given and how participants responded to them. A value was then calculated to show the average response. This was meant to give an indication of their appreciation of TPM and was therefore a preface to the questions that would come in later sections. The respondents basically had a good understanding of TPM with an average rating of 4.2 between the “agree” and “strongly agree” range. The question of whether TPM was the same as 5S had a score of 3.6 which can basically be construed to be lack of understanding of the difference between TPM and 5S. It is already known from literature that 5S is the basic foundation of TPM implementation. Table 6.6 depicts the results of this survey.

Table 6.6 Understanding of TPM

No.	ATTRIBUTE	Response					
		1	2	3	4	5	Overall Rating Calculated Mean
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
1	TPM emphasizes on TOE (Total Employee* Involvement) in improving the efficiency of the manufacturing organizations and not just the manufacturing capability	0.00%	2.27%	2.27%	63.64%	31.82%	4.3
2	Employees will have new roles, better job functions and responsibilities after implementing TPM	4.65%	4.65%	20.93%	39.53%	30.23%	3.9
3	TPM will improve Overall Equipment Effectiveness	0.00%	2.44%	9.76%	39.02%	48.78%	4.3
4	TPM is a maintenance approach that optimizes equipment effectiveness, eliminates breakdowns and promotes operator maintenance through day to day activities involving the total workforce	0.00%	2.33%	6.98%	44.19%	46.51%	4.3
5	TPM aims to reduce the six major losses categorized as breakdown, set up and adjustment, idling and minor stoppages, speed loss, quality defects and rework, start up and yield losses.	0.00%	2.33%	6.98%	44.19%	46.51%	4.3
6	TPM is a group activity that trains operators to share responsibility for routine inspection, cleaning, maintenance and minor repairs through collaboration with maintenance personnel	0.00%	0.00%	6.98%	46.51%	46.51%	4.4
7	TPM is 5S	2.50%	5.00%	40.00%	37.50%	15.00%	3.6
	Overall Rating						**4.2/5**

6.4.2 Understanding Autonomous Maintenance

There was also a good appreciation and understanding of Autonomous Maintenance by the respondents with an average of 4.2 as shown in Table 6.7. The lowest score was 3.9 which was based on the question of a potential conflict between maintenance staff and production. Most of the responses were in the “Agree” and “Strongly Agree” band.

Table 6.7 Understanding of AM

ATTRIBUTE	Response					
	1	2	3	4	5	Overall Rating Calculated Mean
Description	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	
AM will not reduce authority of maintenance staff towards equipment but will ease the burden on maintenance	0.00%	2.63%	23.68%	52.63%	21.05%	3.9
AM brings Production and Maintenance together to perform maintenance work	2.63%	2.63%	7.89%	55.26%	31.58%	4.1
Operators must carry out tasks such as cleaning and inspection, lubrication, precision checks, and simple replacement and repairs	0.00%	2.63%	7.89%	44.74%	44.74%	4.3
AM will teach operators to understand more about their machines and allows timely detection and intervention in abnormal situations	0.00%	0.00%	0.00%	59.46%	40.54%	4.4
On the job Training and a paradigm shift on the role of the operator in the maintenance matrix is required.	0.00%	0.00%	10.53%	42.11%	47.37%	4.4
The current South African Unionised environment makes it difficult to implement Autonomous Maintenance	2.63%	0.00%	28.95%	13.16%	55.26%	4.2
Overall Rating						**4.2/5**

6.4.3 Current Maintenance Practices

This section looked at the four focus areas regarding how maintenance was being carried out in order to check alignment to TPM.

Leadership and Direction Focus: Ten questions explored if there was good leadership and direction focus regarding maintenance practices and the overall rating average on this question was 3.2 which meant that the responses were more inclined towards uncertainty. The lowest rating was 2.2 in response to the question regarding whether maintenance was a responsibility of

everybody and not just maintenance personnel. In terms of practice, this meant that there is no shared responsibility towards maintenance. Table 6.8 shows the results below.

Table 6.8 Leadership and direction

	1	2	3	4	5	
ATTRIBUTES	**Strongly Disagree**	**Disagree**	**Uncertain**	**Agree**	**Strongly Agree**	**Overall Rating**
Everyone values better maintenance as a way to improve business results It is a part of the plant's mission and strategy	5.26%	10.53%	23.68%	26.32%	34.21%	**3.7**
There are written goals, objectives and targets for maintenance improvement that improve business results	13.51%	21.62%	24.32%	13.51%	27.03%	**3.2**
There is a multi-level plant leadership committee that works on continuously improving the maintaining function	13.16%	23.68%	13.16%	34.21%	15.79%	**3.2**
Everyone understands that maintenance is a responsibility of everyone in the plant, not just the maintenance personnel	42.11%	26.32%	5.26%	18.42%	7.89%	**2.2**
The plant insists that scheduled preventive maintenance tasks are done as a part of operational planning	23.68%	23.68%	5.26%	36.84%	10.53%	**2.9**
Maintenance System performance is routinely measured and reported against goals	21.05%	18.42%	21.05%	23.68%	15.79%	**2.9**
The plant has an ultimate goal of zero downtime due to equipment breakdowns	21.62%	21.62%	10.81%	29.73%	16.22%	**3.0**
Everyone understands that equipment must be well maintained to produce a quality product	10.53%	18.42%	13.16%	13.16%	44.74%	**3.6**
Everyone understands that equipment must be well maintained to get best productivity	7.89%	15.79%	13.16%	21.05%	42.11%	**3.7**
Ongoing work in maintaining and improving equipment reliability is valued more than good firefighting type maintenance	18.92%	21.62%	18.92%	18.92%	21.62%	**3.0**
Overall Rating						**3.2/5**

Planned Maintenance: Planned Maintenance is an integral pillar of TPM and hence thirteen attributes were checked on the current maintenance practices. The average response was 2.9, very close to being uncertain. The lowest rating was 1.9 which was on the attribute of effective use of CMMS. Most were uncertain if there was effective use of SAP PM Module in the maintenance practices. The attribute of lubrication scored highest with a rating of 3.7.

Table 6.9 Planned maintenance focus of the company

	1	2	3	4	5	
ATTRIBUTES	**Strongly Disagree**	**Disagree**	**Uncertain**	**Agree**	**Strongly Agree**	**Overall Rating**
There is a formal periodic equipment cleaning/inspection system (PM) in place that identifies potential problems before they become downtime issues	11.43	28.57	17.14	28.57	14.29	**3.1**
Equipment listings and PM Procedures are current and accurate	17.14	20	31.43	17.14	14.29	**2.9**
Preventive maintenance work has the highest priority in the maintenance planning and scheduling effort. Only serious safety, quality and imminent breakdown issues have a higher priority than PM work	14.29	20	11.43	40	14.29	**3.2**
Potential problems are identified and work orders are entered to correct them	14.29	25.71	14.29	37.14	8.57	**3.0**
The majority of repair work orders are generated from preventive maintenance inspections	20	25.71	17.14	28.57	8.57	**2.8**
When a breakdown occurs, preventive maintenance procedures are reviewed and adjusted as necessary to prevent the problem from reoccurring	26.47	29.41	11.76	17.65	14.71	**2.6**
There is a lubrication program that makes sure equipment is lubricated routinely and properly with the proper lubricant	0	18.75	31.25	21.88	28.13	**3.6**
Lubricants and lubrication equipment are stored and maintained properly, to avoid contamination problems	0	15.15	27.27	27.27	30.3	**3.7**
Operating personnel have most of the responsibility for preventive maintenance work that is done while equipment is running	42.42	18.18	18.18	12.12	9.09	**2.3**
There is an ongoing review process involving operators and maintenance personnel to move as much PM from a downtime to a runtime activity	36.36	24.24	21.21	12.12	6.06	**2.3**
There is effective use of SAP, PM module as a Computerised Maintenance Management System package	53.13	12.5	25	9.38	0	**1.9**
Overall Rating						**2.9/5**

Maintenance Administration: This had an average of 2.9 which was more inclined towards the "uncertain" range. However, closer analysis of the results shows almost an even distribution of those who were on both sides of the uncertain range, that is those in disagreement and those in agreement. This is further explained in the analysis section.

Table 6.10 Maintenance administration

	1	2	3	4	5	
ATTRIBUTES	**Strongly Disagree**	**Disagree**	**Uncertain**	**Agree**	**Strongly Agree**	**Overall Rating**
The plant strongly supports the concept of planned and scheduled maintenance as the most efficient, effective way of performing maintenance and all departments are committed to its success	20.59	20.59	8.82	32.35	17.65	**3.1**
A work order system is in place to allow effective management of maintenance work	17.65	20.59	8.82	32.35	20.59	**3.2**
There are individuals in roles dedicated to the planning, scheduling, and coordinating of maintenance work	35.29	2.94	20.59	17.65	23.53	**2.9**
More than 80% of non-emergency Work Orders are planned	14.71	23.53	29.41	26.47	5.88	**2.9**
A weekly maintenance schedule is always prepared and agreed on by operations and maintenance in a weekly meeting	18.18	24.24	24.24	15.15	18.18	**2.9**
The maintenance schedule is reviewed and updated daily and W/Os are assigned to individuals	26.47	8.82	23.53	29.41	11.76	**2.9**
The various reasons for scheduled work not getting done are reviewed and discussed in the weekly maintenance-scheduling meeting	24.24	9.09	48.48	6.06	12.12	**2.7**
Kits of parts planned for work orders are routinely prepared in advance for scheduled work orders	29.41	17.65	8.82	32.35	11.76	**2.8**
It is understood and valued that accurately completed work orders greatly help the planning and scheduling of maintenance work	26.47	8.82	14.71	38.24	11.76	**3.0**
Standard procedures and parts lists have been built and are used for planning repetitive maintenance work	21.21	15.15	30.3	24.24	9.09	**2.8**
Adequate documentation, parts lists, manuals, drawings, etc are readily available, and used in maintenance planning	26.47	17.65	20.59	20.59	14.71	**2.8**
Overall Rating						**2.9/5**

Reliability and Improvement Focus: The focus area of Reliability and Improvement also goes with the pillar of Focused Improvement. As can be seen in the Table 6.11, the overall rating for this was 2.7, which was between disagreeing and uncertainty. However the responses to the attributes were widely varied across the whole range. This is further explained in the analysis section.

Table 6.11 Reliability and improvement focus

	1	2	3	4	5	
ATTRIBUTES	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Overall Rating
Work orders are always completed with all relevant actual information (parts procedures manhours), to allow analysis for recurring problems	21.74	21.74	34.78	17.39	4.35	2.6
Analysis of repair work orders is a regular, routine task, performed with operating teams to avoid breakdowns and improve reliability	13.04	34.78	21.74	26.09	4.35	2.7
Trend information on maintenance downtime and maintenance costs is readily available for each piece of critical equipment and is referred to routinely to generate maintenance work	21.74	30.43	21.74	26.09	0	2.5
There is a formal system to attack equipment problems that involves thoroughly determining the underlying root cause	31.82	22.73	22.73	22.73	0	2.4
Maintenance personnel are available to assist operating teams with reliability improvement analysis and correction	13.64	31.82	27.27	13.64	13.64	2.8
Technical personnel, such as engineers or experienced technicians, are available to assist teams with reliability improvement	4.55	27.27	18.18	27.27	22.73	3.4
Equipment downtime is tracked and reviewed periodically	18.18	31.82	18.18	22.73	9.09	2.7
A reliability team with members from production, engineering, and maintenance review top downtime issues regularly	22.73	31.82	27.27	9.09	9.09	2.5
Overall Rating						**2.7/5**

6.4.4 Evaluation of the Eight TPM Pillars

The 8 pillars of TPM are the basis for its sound implementation. An indication of a general impression of how personnel understood the importance of these pillars was sought in this section. While all the sections above were meant to explore and give a measure of the alignment of maintenance practices to TPM pillars, it was prudent to note how the respondents viewed the values that were assigned to these TPM pillars in the daily maintenance practices. The scale was 1 to 10 with 1 being least important and 10 being the most important.

Overview of the Eight TPM Pillars: This section was meant to capture the general conception of the respondents on the dynamics of the eight TPM pillars in the organization. The results from the scaling of the responses showed that the major pillar that was clearly visible and important was

Safety Health and Environment with a weighted average of 7.43. The second most visible was the Equipment and Process Improvement Pillar, also known as the Focused Improvement Pillar. Autonomous Maintenance faired lowest at 4.25 as shown in Figure 6.4.

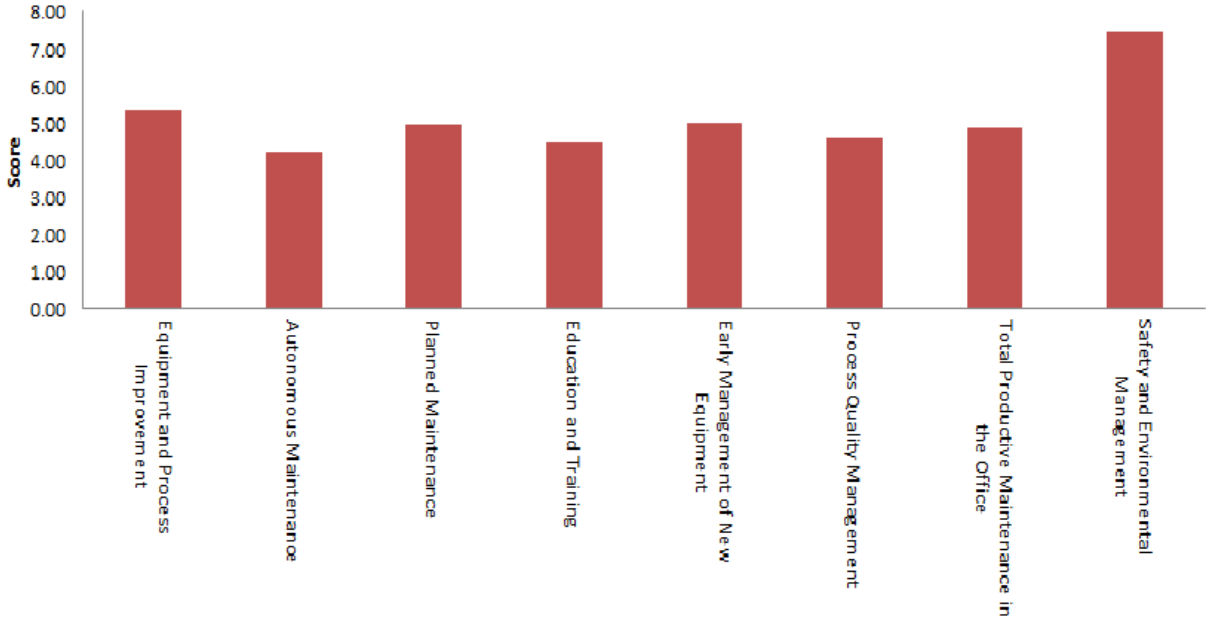


Figure 6.4 TPM pillars overview

6.5 Segregation of Duties

TPM calls for maintenance duties to be separated between Production and Maintenance. This section directly questioned respondents on what was actually happening on the floor. The respondents were asked who was carrying the following common tasks regarding TPM. The results are depicted in Figure 6.5.

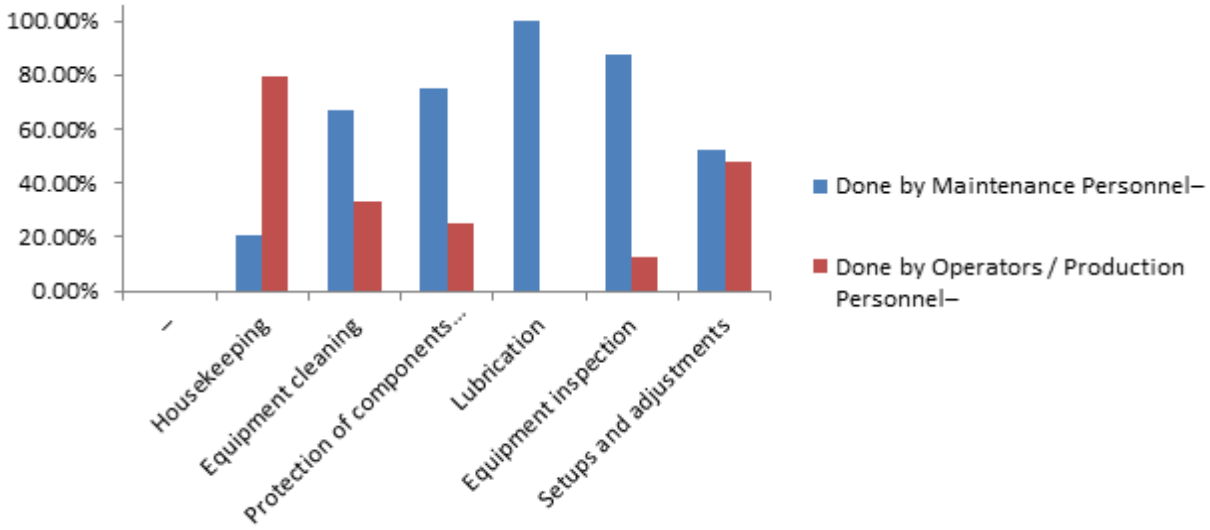


Figure 6.5 Task responsibilities

6.5.1 Duties and responsibilities

In response to direct questioning on what was happening in the four business units, 91% of the respondents were of the view that there was no Autonomous Maintenance practice, 87% noted that operators had no involvement with maintenance, while 63% mentioned that there was no emphasis on Kaizen or improvement effort. The responses are depicted in Figure 6.6.

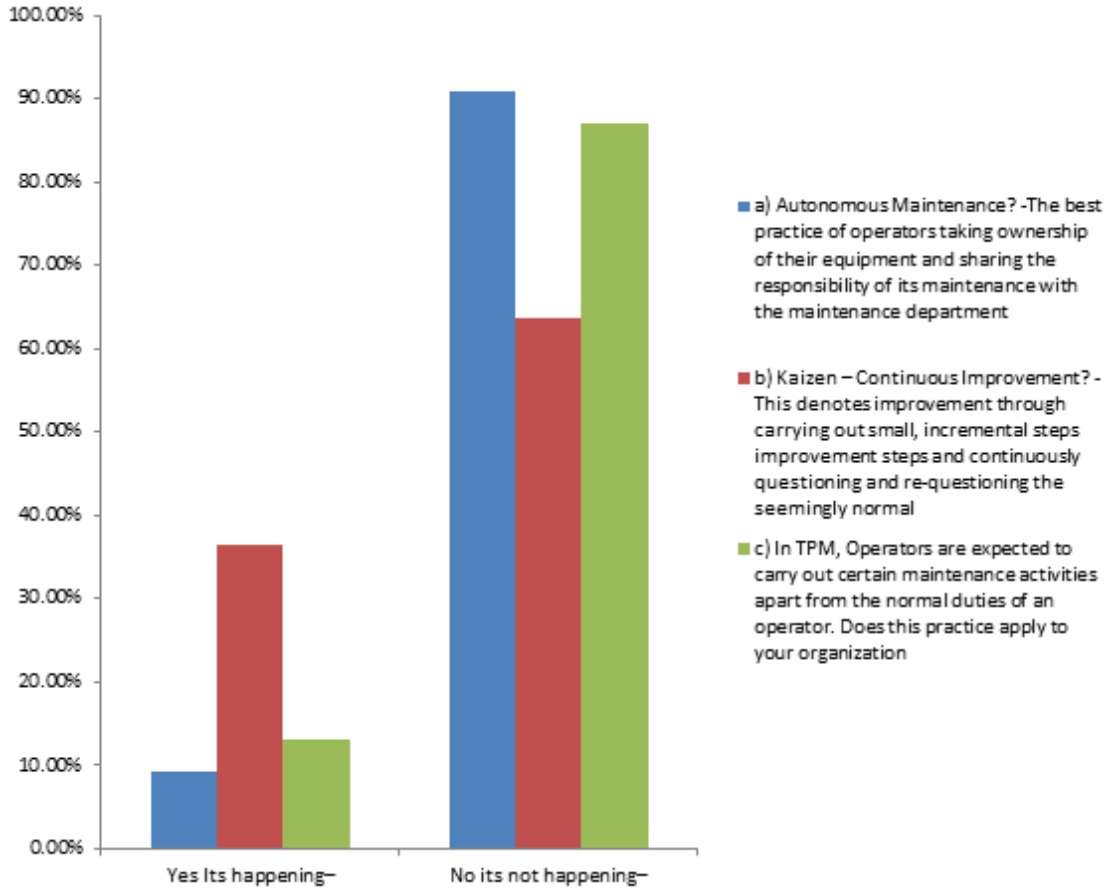


Figure 6.6 AM kaizen or TPM

6.5.2 Operational Environment for TPM Implementation Possibilities

While it is already known that there were minimal ingredients for the implementation of TPM, this section checked on the current operational environment and gathered evidence to determine if TPM implementation was a possibility or something that was remote. The results that came out are presented in Figure 6.7.

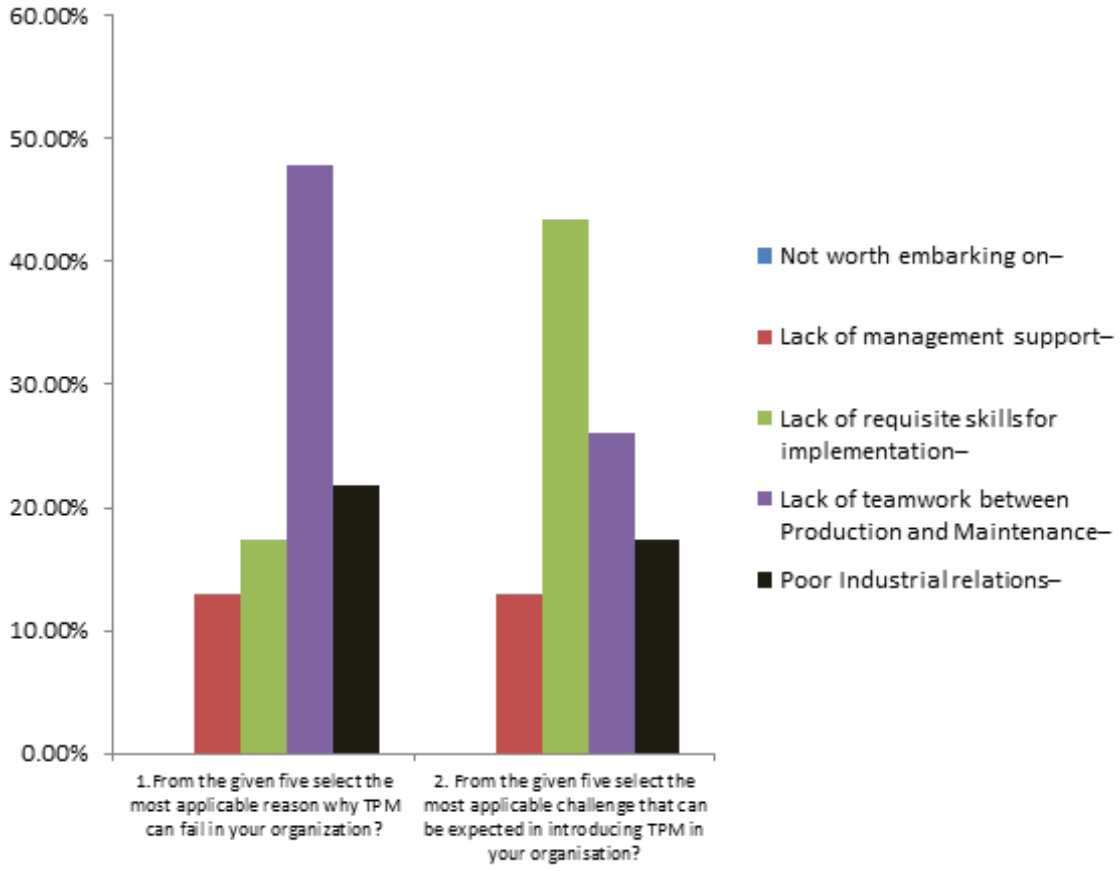


Figure 6.7 TPM potential impediments

6.6 Interviews

The following major issues were raised in interviews

- A clear maintenance policy for the company was lacking because maintenance was carried out only when production felt it was convenient for them to do so hence it was mostly done on Sundays, when production was not running.
- The introduction of TPM in the organization, if not done properly would result in unintended consequences including the possibility of a strike. So strong was this view that union engagement should be a critical part of the consultation process in the

implementation of TPM. Unionized employees have become more and more interested in issues that affect their welfare and job content.

- Skills development also came out as a major theme especially at artisanal levels, and foremen consistently mentioned that they had to always watch out for the poor quality and workmanship of the artisans that they had.

6.7 Conclusion

Detailed information was gathered through performance measures availed from reports, on line survey responses from the four business units and direct interviews with key stake holders. The performance measures were also given by interviewees during the interviews, referring to the records that they had for their reports. The results are analysed on the next chapter.

CHAPTER 7: ANALYSIS OF RESULTS

This section deals with the interpretation and analysis of the results of this survey and checks if the current maintenance practices of the conglomerate are aligned to TPM. The section analyses the Interview results, Performance measures and the On-line survey results.

7.1 Performance Measurement

As has already been shown in the literature survey section, there are various performance measures that are in use to determine maintenance effectiveness. Based on the results, each business unit is represented in terms of performance measures and the requisite TPM Pillar that is impacted and the TPM wheel element affected is shown on Table 7.1. According to the literature survey, a TPM pillar can be related to performance measure in place. For instance, monitoring downtime is a basic proof of the Planned Maintenance and Equipment Process Improvement pillars.

Table 7.1 Performance measures' correlation to TPM Pillar and TPM Wheel

Section	Performance Measure in Place	TPM Pillar	TPM Wheel element
Business Unit A	Downtime, OEE, Line Efficiency, Plant Availability	Planned Maintenance, Equipment Process Improvement	Asset Strategy
Business Unit B	Downtime i.e Lost Times, Percentage Availability	Planned Maintenance, Equipment Process Improvement	Asset Strategy
Business Unit C	Downtime, MTBF, MTTR, Machine Efficiency, Plant Availability	Planned Maintenance, Equipment Process Improvement	Asset Strategy
Business Unit D	Plant Availability, OEE	Planned Maintenance, Equipment Process Improvement	Asset Strategy

The basic measure common to the four business units was downtime duration of equipment. OEE was also shown as a measurement criteria in one business unit. The performance measures were from submitted monthly reports.

The measures only addressed the pillars of PM and Equipment Process Improvement. They also fulfilled the requirement of Asset Strategy on the TPM wheel.

For Business Unit A the OEE target had also been reduced to 50% compared to the world class level of 85% due to inefficiencies. The plant had an average OEE of 43% during the period under review.

Some performance measures that were in use were also pointed out by respondents on the open ended sections of the on line survey and are listed in Table 7.2.

Table 7.2 Respondents' performance measures in relation to TPM Pillar and TPM Wheel

	Performance Measure	Actual Average	Target	TPM Pillar	TPM Wheel
Respondent A	**1** plant availability	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	2 plant utilisation	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	3 energy consumption	not availed	not availed	Quality	Asset strategy
	4 spares cost	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	5 labour cost	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
Respondent B	**1** spares availability	not availed	not availed	PM, Equipment and Process Improvement	Resource Planning and Scheduling
	2 equipment availability	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	3 utilisation	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	4 equipment handling	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	5 energy management	not availed	not availed	Quality	Asset strategy
Respondent C	**1** time efficiency	25%	60%	PM, Equipment and Process Improvement	Asset strategy
	2 job efficiency related to repeat tasks	35%	75%	PM, Equipment and Process Improvement	Asset strategy
	3 planned maintenance	5%	80%	PM, Equipment and Process Improvement	Asset strategy
	4 safety in procedures	85%	100%	Safety	Asset strategy
Respondent D	**1** no. of breakdowns	not availed	not availed	PM, Equipment and Process Improvement	Asset strategy
	2 productive hours vs available hours	not availed	not availed	Equipment and Process Improvement	Resource Planning and Scheduling
	3 safety statistics	not availed	not availed	Safety	Asset Strategy
	4 cost	not availed	not availed	PM, Equipment and Process Improvement	Asset Strategy
	5 downtime	not availed	not availed	PM, Equipment and Process Improvement	Asset Strategy
Respondent E	**1** machine downtime	not availed	not availed	PM, Equipment and Process Improvement	Asset Strategy
	2 machine efficiency	not availed	not availed	PM, Equipment and Process Improvement	Asset Strategy
Respondent F	**1** plant availability	49%	52%	PM, Equipment and Process Improvement	Asset Strategy
	2 mechanical delays	8.00%	8.50%	PM, Equipment and Process Improvement	Asset Strategy
	3 electrical delays	3.20%	3.00%	PM, Equipment and Process Improvement	Asset Strategy
	4 roll shop delays	1.00%	1.50%	PM, Equipment and Process Improvement	Asset Strategy
	5 production delays	25%	22%	PM, Equipment and Process Improvement	Asset Strategy

It is clear from the above that the major TPM Pillars being addressed by the measurements were Planned Maintenance, Equipment and Process Improvement, Safety and Environment Management, and Quality Process Management. This only addressed 50% of the TPM pillars. Only two elements, which are Asset Strategy, and Resource Planning and Scheduling, out of seven, were addressed on the TPM wheel. The other five elements of the TPM wheel i.e Empowerment, Systems and Procedures, Measurement, Continuous Improvement Teams, and Processes were not covered adequately. The Performance measures as presented fell short of the expected TPM implementation requirements.

7.2 Interviews

Focus on the four business units in the face to face interviews produced the results captured in Table 7.3. Analysis of the results was done through matching them with the requirements of the TPM pillars.

The TPM pillars to be matched with the findings were the following:

1. Equipment and Process Improvement
2. Autonomous Maintenance
3. Planned Maintenance
4. Education and Training
5. Early Management of New Equipment
6. Process Quality Management
7. TPM in the Office
8. Safety and Environmental Management

Table 7.3 shows how the interview responses matched the pillars.

Table 7.3 TPM pillars alignment

TPM PILLAR	FINDINGS	OVERALL IMPLICATION
Equipment and Process Improvement	89% fire- fighting mode due to lack of Planned Maintenance More emphasis place on production neglecting maintenance 100% Challenges in lack of spares and consumables Skills of most artisans were not up to standard Budgetary constraints was an issue 90% of jobs were breakdown and 10% were maintenance and planned	Pillar is not addressed
Autonomous Maintenance	100% No operator involvement in maintenance activities Operators did not clean their machines 100% Operators were not active participants in the event of a breakdown and disappeared Operators were alleged to break machines Operators lacked requisite skills and involving them in maintenance would likely cause a strike if they were not compensated.	Pillar is not addressed
Planned Maintenance	100% Reactive maintenance- fire fighting Maintenance done at the convenience of production done during weekends Breakdown to Maintenance Work ratio varies from 50%-90% and 10%-50% respectively. Head of the Engineering department remarked that a structured maintenance program that would be applicable to all units was being implemented Lack of documentation eg manuals and drawings made it difficult to plan certain tasks against a back drop of aged equipment Lack of training has resulted in the limited use of SAP PM module.	Pillar partially addressed
Education and Training	Lack of requisite training for artisans even those with Red seal Lack of training for operators to do Autonomous maintenance Head of Engineering: Review of the company's apprenticeship program to see if it met with the company's objectives.	Pillar partially addressed especially regarding Apprenticeship training program
Early Management of New Equipment	Equipment management fell flat for equipment that is more than 30years old No manuals, drawings and technical information that would support the maintenance effort.	Pillar not addressed
Process Quality Management	Lack of operator training in Autonomous maintenance Operators committed to production issues only and engineering expected to deal with maintenance issues	Pillar not addressed
TPM in the Office	Poor or lack of proper structures for maintenance administration. Maintenance Planners are more involved in buying than Planning Non-existent maintenance policy means there is no drive towards a set target or objectives Head of Engineering confirmed that this was still being developed.	Pillar partially addressed through available of resources like Maintenance Planners and SAP program
Safety and Environmental Management	Great emphasis being placed on SHE mainly due to nature of the operating environment Monthly safety meetings being held Clearly visible signage, posters and up to date statistics boards confirm a commitment to Health and Safety	Pillar being addressed across the board.

Analysis of the Interview questions based on the TPM wheel elements revealed the following information represented in Table 7.4

Table 7.4 TPM Wheel elements alignment

TPM ELEMENT	FINDINGS	OVERALL IMPLICATION
Asset strategy	89% fire- fighting mode due to lack of Planned Maintenance More emphasis place on production neglecting maintenance 100% Challenges in lack of spares and consumables Skills of most artisans were not up to standard Budgetary constraints was an issue 90% of jobs were breakdown and 10% were maintenance and planned	Element is not addressed
Empowerment	100% No operator involvement in maintenance activities Operators did not clean their machines 100% Operators were not active participants in the event of a breakdown and disappeared Operators were alleged to break machines Operators lacked requisite skills and involving them in maintenance would likely cause a strike if they were not compensated. Lack of requisite training for artisans even those with Red seal Lack of training for operators to do Autonomous maintenance Head of Engineering: Review of the company's apprenticeship program to see if it met with the company's objectives.	Element is partially addressed through investment in Training.
Resource Planning and Scheduling	100% Reactive maintenance- fire fighting Maintenance done at the convenience of production done during weekends Breakdown to Maintenance Work ratio varies from 50%-90% and 10%-50% respectively. Head of the Engineering department remarked that a structured maintenance program that would be applicable to all units was being implemented Lack of documentation eg manuals and drawings made it difficult to plan certain tasks against a back drop of aged equipment Lack of training has resulted in the limited use of SAP PM module.	Element partially addressed
Systems and Procedures	Equipment management fell flat for equipment that is more than 30years old No manuals, drawings and technical information that would support the maintenance effort. Poor or lack of proper structures for maintenance administration. Maintenance Planners are more involved in buying than Planning Non-existent maintenance policy means there is no drive towards a set target or objectives Head of Engineering confirmed that this was still being developed.	Element not addressed
Measurement	Performance was being measured	Element partially addressed
Continuous Improvement Team	Non – existent	Element not addressed
Process	Lack of operator training in Autonomous maintenance Operators committed to production issues only and engineering expected to deal with maintenance issues	Element not addressed

7.3 Online Responses

The online survey structure was analysed to check for TPM alignment and understanding. The first section analysed the respondents' TPM understanding while the second section analysed maintenance practices in form of routine and mundane maintenance activities done in the sections. The third section was an introspection of how the respondents rated themselves against the eight TPM pillars.

Table 7.5 TPM pillars alignment

Attribute	Rating out of 5	Applicable TPM Pillar	Applicable TPM Element	Implications
Understanding TPM	4.2	Education and Training	Empowerment	Elements and Pillars matched favorably
Understanding Autonomous Maintenance	4.2	Autonomous Maintenance	Systems and Procedures	Elements and Pillars matched favorably
Leadership and Direction focus	3.2	Early Management of new Equipment, TPM in the Office	Continuous Improvement Teams	Elements and Pillars poorly matched
Planned Maintenance	2.9	Planned Maintenance	Processes	Elements and Pillars poorly matched
Maintenance Administration	2.9	Process Quality Management, Safety and Environmental Management	Asset Strategy, Measurement	Elements and Pillars poorly matched
Reliability and Improvement Focus	2.7	Equipment and Improvement Focus	Continuous Improvement Teams, Measurement, Asset Strategy	Elements and Pillars poorly matched

7.3.1 Level of TPM Understanding

The average rating for all the questions on TPM understanding was 4.2/5 which was an endorsement of respondents' sound knowledge of TPM as a maintenance strategy. The respondents exhibited a good understanding and appreciation of TPM. Further analysis of Table 6.6 shows that the responses to attributes 1, 4, 5 and 6 were more inclined towards the "agree" and "strongly agree" responses and all of them had an average above 90%.

This meant that the respondents were more amenable to the use of TPM as a maintenance strategy and the same people would be central to accepting TPM implementation.

The understanding of TPM lays the foundation for the adoption of the pillars of Education and Training, and Planned Maintenance and conforms to the TPM wheel support foundations of Asset strategy and Empowerment.

Level of AM Understanding: Autonomous Maintenance is a critical pillar of TPM making it important to analyse respondents' views. The responses were more inclined towards the "agree" and "strongly agree" option of AM with an average of 4.2/5. The first two questions related to understanding of AM and the positive impact that emanates from its implementation.

On the first question, 74% of the respondents disagreed and strongly disagreed on the positive impact of TPM while 87% did the same on the second question.

Operator involvement in TPM was favorably rated by the respondents and it was encouraging to note the optimistic views with a combined score of between 90% and 99% being agreements.

However respondents felt that change was needed regarding the interaction between Operators and Maintenance. They also felt the unionized environment needed to be negotiated with in a manner that would avoid unnecessary expectations and frustrations. The respondents' appreciation of AM was borne out of future expectations and not because of what was currently happening. Greater complementary interaction between Production and Maintenance was called for.

7.3.2 Maintenance Practices

The analysis of the maintenance practices focused on the following areas:

Leadership and Direction

Planned Maintenance

Maintenance Administration

Reliability and Improvement

Analysis of this section also revealed that an average of 3 did not necessarily mean that the majority of the respondents were uncertain. A closer look was needed since as it also could have meant an even scatter or distribution of the respondents' views across the whole scale.

Leadership and Direction: This section produced an average of 3.2 which may be interpreted as respondents being uncertain of the attributes that were being looked at. However further mathematical analysis actually showed that this was not due to the majority of the respondents answering "uncertain" but was due to an even scatter of the responses across the whole scale.

Prominently, 42% strongly disagreed and 26% disagreed on the assertion that "Everybody understands that maintenance is a responsibility of everyone in the plant, not just maintenance personnel." This statement is tied to AM, and Equipment and Process Improvement (Focused Improvement) and shows clearly that Leadership and Direction focus is not meeting the expectations of TPM regarding the two pillars. There was no other attribute that had a massive stand out where disagreeing and agreeing were scored in almost the same measure. This implied the existence of pockets of good and bad practices in the same measure. It can only give some sense of hope that the good practices would influence the whole set up to adopt and improve on Leadership and Direction.

Planned Maintenance: A PM culture is a positive step towards TPM implementation and is one of the eight TPM pillars. An average of 2.9 was scored for PM. Further analysis of the individual attributes showed that 53% of the respondents strongly disagreed that SAP was effectively being used as a CMMS. The approach to lubrication was rated favourably regarding organization, storage and control. Again the AM aspect was rated poorly with a value of 2.4.

Maintenance Administration: This also scored an average of 2.9, just below the uncertain range and hence it was important to look at the individual scores. Only 3 out of 11 attributes had an average score that was 3 or above. The rest were below 3 implying that those attributes were rated unfavorably being on disagree and strongly disagree side. Maintenance Administration ties in well with the "TPM In The Office" pillar. Despite having pockets of excellence in some areas, Maintenance Administration was rated poorly, implying that mechanisms for an efficient and effective TPM administration were not in place.

For instance, 48% of the respondents were uncertain on whether scheduled work that would not have been carried out was ever followed on, analysed and reviewed. This can be attributed to PM not being visible to other stakeholders and also due to poor maintenance administration. It also demonstrated poor focus on equipment improvement.

This showed that more still needed to be done in terms of improving maintenance administration.

Reliability and Improvement Focus: This section focused on Reliability and Improvement which was also a measure of how the Equipment Improvement pillar and PM pillar were viewed. The average score was poor at 2.7. The attribute that had the highest score of 3.4 was on the availability of engineers and technicians being able to assist with reliability improvement. However, the other 7 remaining attributes out of the 8, all rated Reliability and Improvement focus negatively. This means that the current maintenance practices were not fully aligned to the requirements of the Equipment and Process improvement pillar.

7.4 Overall Alignment to Maintenance Practices

Table 7.1 and 7.2 showed the performance measures that were used in the engineering reports as well as measures used in other departments. The Pillars that the measures were aligned to were Planned Maintenance, and Resource Planning and Scheduling. Of the eight pillars, the maintenance practices were aligned to two pillars. Of the seven TPM Wheel elements, only one element of Asset Strategy was found to be aligned with the maintenance practices in use.

Based on the Interview responses, it was found that the TPM Pillar of Safety and Environmental Management was being fully addressed and practices were aligned to the requirements of the Pillar. However, the maintenance practices were not aligned to the other seven pillars. TPM in the Office, and Education and Training were found to be partially aligned. The maintenance practices did not cover the TPM wheel elements and only two, Measurement, and Resource Planning and Scheduling were found to have been covered.

The results of the online responses showed that two TPM Pillars of Education and Training, and Autonomous maintenance were understood by the respondents. The TPM Wheel elements of Empowerment, and Systems and Procedures were also found to be dominant in the maintenance practices. This is because they all had scores rating of 4.2.

The maintenance practices were not aligned to six TPM Pillars and five TPM wheel elements.

Overall, the maintenance practices were not fully aligned to TPM.

CHAPTER 8: DISCUSSION

8.1 Implications of the Results from the Research

This section deals with the results and analysis of this survey and propose recommendations on the way forward. Information was gathered for the research on the maintenance practices in the conglomerate and investigations were conducted to check if they were aligned to TPM practices. The research identified the deficiencies or shortcomings of the current system, and gave a qualitative measure of the alignment of maintenance practices. It reveals the difficulties that this conglomerate will have to deal with if TPM is to be implemented.

8.2 Alignment to TPM pillars

The trio of online survey, performance measures and interviews all pointed out deficiencies in the alignment of maintenance practices to TPM. The three approaches produced a set of results regarding how the practices were aligned to the eight pillars of TPM and the seven elements on the TPM wheel. After tabulating the implications of the responses given, these were then matched against the requirements of TPM pillars and elements to determine a level of compliance for each. The level of compliance was determined by how a particular practice was emphasized based on the number of responses and times that it was mentioned by the respondents. The limitation of the approach was that respondents may have forgotten certain key issues that they practised or lacked. However, the data collected did not show any extreme variations in terms of the responses. As such the data was taken as valid and reliable to allow for authentic conclusions to be given.

None of the pillars, except the Health and Safety one, came out with a rating that was higher than 50% . This was revealed by the online survey, interview and how the respondents rated themselves. The emphasis on Health and Safety is clearly visible with a separate department that deals with safety.

The adoption of Autonomous Maintenance is still very lowly rated, with the majority of respondents agreeing that it is good but admitting that it was not being done. The traditional approach of having operators only producing, and having nothing to do with maintenance is still

affixed on people's the mind-set. The respondents mentioned that giving workers extra responsibilities without extra compensation would result in industrial action. This would be made even worse if this was not matched with an increase in wages. The unions would also make an issue out of this since they would feel that their members would be doing work that they are ordinarily not supposed to do. AM is one of the most important steps in TPM and is the first step towards adoption of the complete program.

TPM in the Office also scored a very low rating of less than 3 out of 10. In spite of having a CMMS system in SAP, respondents were not getting the necessary value out of the system.

Results also showed that record keeping was poor. There were no drawings or manuals for equipment and yet some of it was over 30 years old. Reports that were being produced were merely trending breakdown durations in most cases but did not calculate plant availability. No visible effort was seen in terms of formal improvement plans.

Two business units were interested in OEE as a performance measure while other plants emphasized more on production tonnages versus budget. This lack of appreciation of OEE affects improvement efforts across the whole plant strategy because it means the key variables of design rate and quality will be ignored. These are critical parameters for decision making, especially capital investment decisions and plant improvement initiatives.

Lubrication of equipment was one item that was rated highly. While it was being done by maintenance personnel 100% of the time, there was some structure and organization centred on equipment lubrication. As shown in the literature survey, lubrication, though very important was a basic maintenance strategy that was first employed in the 1940s. It is an early approach to maintenance and is expected in an organization where a proper Planned Maintenance strategy is still to be established. There was no maintenance policy in place according to 100% of the respondents. They also mentioned that maintenance was being done only on weekends when the plant was made available for such. Indeed not all work can be done during a weekend and maintenance personnel would end up doing what is practically possible within the time limits. The most practical way would be to delay such work until the plant fails. Without a background practice of PM, TPM becomes a difficult system to implement.

Poor Early Management of Equipment was an issue that was strikingly exposed by the lack of equipment drawings and manuals. Poor document control and management of change was part of the culture of the organization that continued to evolve as the organization grew. This resulted in serious challenges facing new maintenance personnel especially regarding trouble shooting. It meant that one would make his own un-recorded changes to process without any need for verification and follow up. Such an organization would depend on the strength of individuals rather than systems. This has a downstream effect on equipment process improvement and quality process improvement.

The basic foundation of TPM is 5S. The practice of 5S was perceived to be non-existent and factory visits and observed practices also confirmed that this was the case.

The level of skills of artisans and operators was constantly raised as an issue that would impede effective implementation of TPM. This implies that there are no effective mechanisms to upgrade the skills of existing personnel or to align training programs with the requirements of the conglomerate.

8.3 Alignment to Elements of TPM wheel

The seven elements of TPM are all centred on the four themes of Training, Decentralization, Maintenance preventions and Multi-skilling. Training should form part of the continuous improvement effort and this still needs to be vigorously pursued with programs that fit the requirements for successful TPM implementation. The alignment of maintenance practices to TPM will happen if a full understanding and appreciation of TPM is given to employees so that they get the necessary buy in. This can only be done in a culture where training is continuous and forms part of the continuous improvement effort.

Decentralization comes in with the element of employee empowerment where responsibilities are given to employees to make decisions. In such an environment, employees would have been adequately trained to make operational decisions that impact and improve their job processes. The research results showed that there is no AM practice and hence decentralization is still lacking.

Maintenance Prevention is a concept where one minimizes the requirements for maintenance to the least. This begins at the design stage of any equipment or process. The less the time needed for

maintenance, the more time that maintenance personnel and specialists can spend on further process improvement issues and TPM. Currently the conglomerate is in a fire-fighting mode as aptly described by the head of Engineering. Maintenance Prevention has not been accomplished yet.

Multi-skilling is at the core of TPM and operators must feel free to learn to operate as many machines, giving valuable flexibility to production requirements and creating a wide knowledge base. This is unfortunately not the case and that ideal will continue to be hampered by current labour relations issues. AM acceptance across the board is supposed to be the first step and its adoption will make it easier to align to other TPM issues.

8.4 Conclusion

The implementation of any new process or program is made easier if the groundwork for its implementation is in existence. The research revealed that maintenance practices in this conglomerate were not in line with the requirements of TPM. Breakdown maintenance or fighting fires was the approach that was in use most of the time. This was exacerbated by the fact that greater priority was given to production and the achievement of targeted output, thereby rendering maintenance activities as a distraction. Unfortunately, such view of maintenance resulted in a culture with an affront to maintenance with bad consequences to operation. While the conglomerate has invested heavily in SAP as an enterprise and resourcing tool, the use of the PM module is very limited, wasting the huge potential that this tool has.

TPM is a sensitive issue especially as it involves multi skilling and multi-tasking, and in most cases, without commensurate increase in remuneration. As such, sound industrial relations are important for TPM, and companies must be prepared to invest, from the onset, in TPM implementation. There are obvious attributes that ensure that maintenance practices are aligned to TPM and the major ones are the eight pillars for TPM implementation. These should be put into practice first before the official onset of TPM implementation. The maintenance practices were deficient in terms of making the conglomerate ready to adopt TPM.

Only the Health and Safety Pillar was prominent in terms of alignment to TPM. This can be explained by the fact that the metal industry naturally emphasizes health and safety because of the

inherent risks in this operation. Huge investments are made on safety and the environment and a separate department of Health and Safety is common. However, the other seven pillars were ranked lower than 50% across all the approaches of the research. In order to bring the necessary attributes closer to TPM implementation, more emphasis is needed to address the shortcomings that emerged out of the research. Early Equipment Management was poor and there was no evidence of maintenance prevention included in the initial stages of the design.

An alternative framework to TPM was therefore, proposed in this research where emphasis was made on continuous improvement of maintenance practices. These are supposed to be periodically reviewed, and stretch targets set for improvement.

Further studies may be required in companies that have sound maintenance practices, especially those aspiring for world class manufacturing to see how their maintenance would have evolved from what it was before implementation. This is likely to show the uniqueness of the South African labour environment and may add further information on the ideal environment that aligns maintenance practices to TPM implementation.

As a start, the basics of TPM implementation have to be done first especially getting the necessary buy in from unions and improving the industrial relations with employees. This would allow operators to buy into the issue of Autonomous Maintenance and encouragement of the 5S elements. A more effective PM program is required, including proper record-keeping thereof as an effective way of aligning the daily practices towards TPM. A positive culture change would definitely assist in the alignment of maintenance practices to TPM.

The availability of a clear maintenance policy with clear and distinct key performance indicators is a step forward in terms of TPM alignment. This is more applicable to conglomerates where, under normal circumstances, one would expect the approach to maintenance to be uniform. This would allow measures to be analysed and compared and establish benchmarks for continuous improvement. As such, some business units were lowering the targets for performance. In one unfortunate instance, operator performance was reduced to a target of 50% and those with 35% would actually celebrate, feeling that they have achieved 70%.

This research was for academic purposes and not intended to sell TPM as the best maintenance strategy. There are many options that can be carried out depending on an organization's circumstance. However, TPM is one of the latest maintenance approaches on board. This research has highlighted the circumstances under which a TPM program becomes more difficult to implement.

In the same vein, it has proposed methods to align maintenance practices to TPM before the company decides to go for a TPM route. Further research is required on companies that are already having TPM to also determine the difficulties that they went through and the impediments they are facing while implementing TPM. Further study should take TPM use as a maintenance approach within the context of the South African environment and explore the kind of skills that will be required for proper TPM implementation. It may also look at how the curricula for the training of artisans may be revamped to produce artisans who can be regarded as technical operators. These would have the aptitude to adopt and practice TPM in the work place.

CHAPTER 9: CONCLUSION

This study identified the maintenance practices of a conglomerate and checked if the practices were aligned to TPM best practices. The results clearly showed that the maintenance practices did not conform to TPM best practices. As such, more effort would be required to introduce TPM in this organization.

A framework for assessing alignment to TPM best practice was developed and employed in the study. Gaps between observed practices and TPM best practices were identified and recommendations to close the gaps were proffered. The closure of the gaps would make it easier for the organization to implement TPM in future.

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APPENDICES

Appendix A Ethical Considerations

A1 Letter of Authorization to collect data from Head of Engineering

To: Products Engineering.

From: Nicky Louw
Re: Supporting Emmanuel Mabwe in his research as required by his studies

Emmanuel is currently registered at the University of Witwatersrand as an MSc Mechanical Engineering student.

As part of his study programme, he is required to conduct research into a project of his choice. The topic he chose for his research project, is Total Productive Maintenance (TPM). The outcome of this research, will not only be to his benefit, but will be beneficial to also.

I hereby request that we give him our support by making time available in our daily activities to complete the questionnaire. The accuracy of this will depend on the number of questionnaires completed and the audience. The questionnaires will therefore not be limited to the engineering functions only, but we request that other functions participate too.

Thank you for your support.

Regards

25/10/2013.

Nicky (Pr.Cert.Eng)
Engineering Manager: Maintenance
Tel: +27 11
Direct: +27
Mobile: +27

A2: Confidentiality Agreement with Training Manager

10 September 2014

Permission to use Scaw Data -Emmanuel Mabwe, MSc studies, University of Witwatersrand

This serves to confirm that is aware and authorised Emmanuel Mabwe to continue using the data including but not limited to KPI, Performance data, financial data that he obtained during the course of his studies while under the employment of Scaw Metals.

Scaw has already supported Emmanuel with data for his questionnaires and that in addition to that, they are happy for to use company data (KPIs etc) for his studies study and that it's agreed that the company's name and any individual's names will be excluded from the report and any presentations. Scaw has always been supportive of Emmanuel's studies and wishes him well with his final research report.

I, Emmanuel Mabwe, do understand and agree with the contents of this letter.

Agreed: .....
Emmanuel Mabwe

Signed: .....

Training Manager

APPENDIX B Data Inputs

B1: Plant D Measurement Definitions

Definitions:

- Calender Time: The total minutes in the calendar month. This will be 24 x No of days in the month x 60
- P Unused Available Time: This is the time that the plant would not have run while it was available for any other reason – e.g too high stock levels.
- Utilised Available Time: This will be the difference calendar time and the unused available time
- Q Planned Maintenance Time: This is the duration of all planned maintenance activities that were done during the month.
- Gross Operational Time: It's the Utilised Available Time less Planned Maintenance Time
- S External Breakdown: This is breakdown that is caused by external factors that the plant cannot influence e.g Eskom power, or shortage of raw material due to transport issues for instance.
- Available Operation Time: This will be Gross Operational Time less External Breakdown Time.
- T1 Internal Production Delays: This is the duration of the delays that are caused by production issues during operation, e,g waiting for operator adjustments.
- T2 Internal SIN Breakdowns: This is the duration of actual breakdowns that happen in the sinter plant.
- T3 Internal RMH Breakdowns: RMH is the Raw Material Plant. This plant is upstream of the sinter plant and facilitates the storage and conveyance of the sinter to the Blast furnaces. Stoppages upstream can affect the sinter plant that one will need to stop feeding more material to the Blast furnaces as required and hence such delays are recorded as T3.
- T4 Internal FMB Breakdowns: FMB is the Fine Material Blending plant. This plant is downstream of the Sinter Plant and feeds it with raw material used to form sinter. As such any stoppages that happen there are also measured as long as they stop delivery of material to the Sinter material bins.

- T5 Development Delay Time: This is the time of plant stoppages occurring while research or investigations into new recipes or processes are being carried out.
- Planned Maintenance Ratio: This is the net ratio of PM Time over the Total Available Time and is a measure of performance emphasis. The higher the percentage value, the less time the plant was down for maintenance.
- S External Availability Ratio: This is the net percentage remaining from the time that the plant was affected by external downtimes over the Gross Operational Time.
- Sinter Maintenance Availability Ratio: This the net percentage remaining of the downtime for Sinter Internal downtime combined with the downtime of Development delays over the Available Operational Time.
- RMH & FMB Maintenance Availability Ratio: This is the net percentage remaining of downtime for Sinter Internal RMH combined with Sinter Internal FMB over the Available Operational Time.
- Total Maintenance Availability Ratio: This is the net percentage remaining of all downtime over the Gross Operational Time.
- Available Time Ratio (AR): This is the net percentage of the Unused Available Time, Planned Maintenance Time and Total Internal Sinter Production delays over the Total Calendar Time.
- Total Plant Availability (OEE): This is the percentage of the Calendar Time less all Delays over the Calendar Time.

B2: TPM Pillars Rated Score

TPM Pillar	SCORE										
ATTRIBUTE	1	2	3	4	5	6	7	8	9	10	Weighted Average
a. Equipment and Process Improvement (focusing in a clear way the wished improvement in business)	0.00%	8.33%	0.00%	12.50 %	33.33 %	25.00 %	12.50 %	8.33%	0.00%	0.00%	**5.38**
b. Autonomous Maintenance (best practice of operators taking ownership of their equipment and sharing the responsibility of its maintenance with the maintenance department)	0.00%	25.00 %	25.00 %	12.50 %	16.67 %	4.17%	0.00%	12.50 %	0.00%	4.17%	**4.25**
c. Planned Maintenance (effectively planning and controlling of maintenance, with daily planning and planning of stops)	0.00%	16.67 %	20.83 %	8.33%	8.33%	12.50 %	20.83 %	8.33%	4.17%	0.00%	**4.96**
d. Education and Training (enhancing personal relationship,technical and management skills of maintenance people and operators.)	4.17%	20.83 %	12.50 %	12.50 %	16.67 %	8.33%	16.67 %	8.33%	0.00%	0.00%	**4.50**
e. Early Management of New Equipment (attendance of maintenance people since the conception of new projects or acquisitions)	4.17%	4.17%	4.17%	16.67 %	37.50 %	16.67 %	12.50 %	4.17%	0.00%	0.00%	**5.00**
f. Process Quality Management (establishment of a zero defect program.	12.50 %	8.33%	12.50 %	16.67 %	16.67 %	12.50 %	8.33%	4.17%	8.33%	0.00%	**4.58**
g. Total Productive Maintenance in the Office (efficiency—involvement of the administration in TPM program)	8.33%	8.33%	4.17%	29.17 %	12.50 %	8.33%	12.50 %	16.67 %	0.00%	0.00%	**4.88**
h. Safety and Environmental Management (establishment of a health, safety and sustainable environmental system)	0.00%	4.17%	0.00%	4.17%	8.33%	12.50 %	4.17%	37.50 %	16.67 %	12.50 %	**7.46**

B3: On line Survey Questionnaire Structure

Part One:

The following questions are necessary **to establish the demographics of the respondents**:

1. Select from the category that best describes your position in the company

   1.1. Maintenance ☐

   1.2. Production ☐

   1.3. Projects ☐

   1.4. Reliability ☐

   1.5. Quality ☐

   1.6. Other _____

2. What is your current job title_____

3. How many years have you been with the organization _____Years

4. What is the number of employees in your business unit? Tick the appropriate box

1-50	☐	51-100	☐
101-300	☐	301-500	☐
Above 500	☐		

5. What are the main functions of your business unit?

_____

6. Which of the following best describes your understanding of TPM (Total Productive Maintenance).

Description	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
TPM emphasizes on TOE (Total Employee Involvement) in improving the efficiency of the manufacturing organizations and not just the manufacturing capability					
Employees will have new roles, better job functions and responsibilities after implementing TPM					
TPM will improve Overall Equipment Effectiveness					
TPM is a maintenance approach that optimizes equipment effectiveness, eliminates breakdowns and promotes operator maintenance through day to day activities involving the total workforce					
TPM aims to reduce the six major losses categorized as breakdown, set up and adjustment, idling and minor stoppages, speed loss, quality defects and rework, start up and yield losses.					
TPM is a group activity that trains operators to share responsibility for routine inspection, cleaning, maintenance and minor repairs through collaboration with maintenance personnel					
TPM is 5S					

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7. Which of the following best describes your understanding of AM (Autonomous Maintenance)?

Description	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
AM will not reduce authority of maintenance staff towards equipment but will ease the burden on maintenance					
AM brings Production and Maintenance together to perform maintenance work					
Operators must carry out tasks such as cleaning and inspection, lubrication, precision checks, and simple replacement and repairs					
AM will teach operators to understand more about their machines and allows timely detection and intervention in abnormal situations					
On the job Training and a paradigm shift on the role of the operator in the maintenance matrix is required.					
The current South African Unionised environment makes it difficult to implement Autonomous Maintenance					

Part Two: ***Which of the following best describes your current maintenance approach?***

1: Strongly Disagree 2: Disagree 3: Uncertain 4: Agree 5: Strongly Agree ***Please circle one option (1; 2; 3;4 or 5)***

1. Leadership and Directional Focus

1	Everyone values better maintenance as a way to improve business results It is a part of the plant's mission and strategy	*1*	*2*	*3*	*4*	*5*
2	There are written goals, objectives and targets for maintenance improvement that improve business results	*1*	*2*	*3*	*4*	*5*
3	There is a multi-level plant leadership committee that works on continuously improving the maintaining function	*1*	*2*	*3*	*4*	*5*
4	Everyone understands that maintenance is a responsibility of everyone in the plant, not just the maintenance personnel	*1*	*2*	*3*	*4*	*5*
5	The plant insists that scheduled preventive maintenance tasks are done as a part of operational Planning	*1*	*2*	*3*	*4*	*5*
6	Maintenance System performance is routinely measured and reported against goals	*1*	*2*	*3*	*4*	*5*
7	The plant has an ultimate goal of zero downtime due to equipment breakdowns	*1*	*2*	*3*	*4*	*5*
8	Everyone understands that equipment must be well maintained to produce a quality product	*1*	*2*	*3*	*4*	*5*
9	Everyone understands that equipment must be well maintained to get best productivity	*1*	*2*	*3*	*4*	*5*
10	Ongoing work in maintaining and improving equipment reliability is valued more than good firefighting type maintenance	*1*	*2*	*3*	*4*	*5*

2. Planned Maintenance Focus of the company

This section is a measure of the level of understanding and commitment attached to preventive maintenance activity by the plant overall.

1	There is a formal periodic equipment cleaning/inspection system (PM) in place that identifies potential problems before they become downtime issues	*1*	*2*	*3*	*4*	*5*
2	Equipment listings and PM Procedures are current and accurate	*1*	*2*	*3*	*4*	*5*
3	Preventive maintenance work has the highest priority in the maintenance planning and scheduling effort. Only serious safety, quality and imminent breakdown issues have a higher priority than PM work	*1*	*2*	*3*	*4*	*5*
4	Potential problems are identified and work orders are entered to correct them	*1*	*2*	*3*	*4*	*5*
5	The majority of repair work orders are generated from preventive maintenance inspections	*1*	*2*	*3*	*4*	*5*
6	When a breakdown occurs, preventive maintenance procedures are reviewed and adjusted as necessary to prevent the problem from reoccurring	*1*	*2*	*3*	*4*	*5*
7	There is a lubrication program that makes sure equipment is lubricated routinely and properly with the proper lubricant	*1*	*2*	*3*	*4*	*5*
8	Lubricants and lubrication equipment are stored and maintained properly, to avoid contamination Problems	*1*	*2*	*3*	*4*	*5*
9	Operating personnel have most of the responsibility for preventive maintenance work that is done while equipment is running	*1*	*2*	*3*	*4*	*5*
10	There is an ongoing review process involving operators and maintenance personnel to move as much PM from a downtime to a runtime activity	*1*	*2*	*3*	*4*	*5*
11	There is effective use of SAP, PM module as a Computerised Maintenance Management System package	*1*	*2*	*3*	*4*	*5*

3. Maintenance Administration

This section is a measure of the level of understanding, value and commitment to the major administrative aspects of the maintenance system.

1	The plant strongly supports the concept of planned and scheduled maintenance as the most efficient, effective way of performing maintenance and all departments are committed to its success	*1*	*2*	*3*	*4*	*5*
2	A work order system is in place to allow effective management of maintenance work	*1*	*2*	*3*	*4*	*5*
3	There are individuals in roles dedicated to the planning, scheduling, and coordinating of maintenance work	*1*	*2*	*3*	*4*	*5*
4	More than 80% of non-emergency Work Orders are planned	*1*	*2*	*3*	*4*	*5*
5	A weekly maintenance schedule is always prepared and agreed on by operations and maintenance in a weekly meeting	*1*	*2*	*3*	*4*	*5*
6	The maintenance schedule is reviewed and updated daily and W/Os are assigned to individuals	*1*	*2*	*3*	*4*	*5*
7	The various reasons for scheduled work not getting done are reviewed and discussed in the weekly maintenance-scheduling meeting	*1*	*2*	*3*	*4*	*5*
8	Kits of parts planned for work orders are routinely prepared in advance for scheduled work Orders	*1*	*2*	*3*	*4*	*5*
9	It is understood and valued that accurately completed work orders greatly help the planning and scheduling of maintenance work	*1*	*2*	*3*	*4*	*5*
10	Standard procedures and parts lists have been built and are used for planning repetitive maintenance Work	*1*	*2*	*3*	*4*	*5*
11	Adequate documentation, parts lists, manuals, drawings, etc are readily available, and used in maintenance planning	*1*	*2*	*3*	*4*	*5*

4. Reliability Improvement

This section deals with aspects of the use and value of collected data and its synthesis and the approach to corrective actions in order to avoid recurrence of problems.

1	Work orders are always completed with all relevant actual information (parts procedures manhours), to allow analysis for recurring problems	*1*	*2*	*3*	*4*	*5*
2	Analysis of repair work orders is a regular, routine task, performed with operating teams to avoid breakdowns and improve reliability	*1*	*2*	*3*	*4*	*5*
3	Trend information on maintenance downtime and maintenance costs is readily available for each piece of critical equipment and is referred to routinely to generate maintenance work	*1*	*2*	*3*	*4*	*5*
4	There is a formal system to attack equipment problems that involves thoroughly determining the underlying root cause	*1*	*2*	*3*	*4*	*5*
5	Maintenance personnel are available to assist operating teams with reliability improvement analysis and correction	*1*	*2*	*3*	*4*	*5*
6	Technical personnel, such as engineers or experienced technicians, are available to assist teams with reliability improvement	*1*	*2*	*3*	*4*	*5*
7	Equipment downtime is tracked and reviewed periodically	*1*	*2*	*3*	*4*	*5*
8	A reliability team with members from production, engineering, and maintenance review top downtime issues regularly	*1*	*2*	*3*	*4*	*5*

Part Three

1. To what extent does the company value the importance of the following through its current maintenance practices?: **(Rate this 1 to 10 - with 1 being least important and 10 being very important)**

TPM Pillar	Rating of Importance scale (1-10)	Please justify your reason for the rating
a. Equipment and Process Improvement (focusing in a clear way the wished improvement in business)		
b. Autonomous Maintenance (best practice of operators taking ownership of their equipment and sharing the responsibility of its maintenance with the maintenance department)		
c. Planned Maintenance (effectively planning and controlling of maintenance, with daily planning and planning of stops)		
d. Education and Training (enhancing personal relationship,technical and management skills of maintenance people and operators.)		
e. Early Management of New Equipment (attendance of maintenance people since the conception of new projects or acquisitions)		
f. Process Quality Management (establishment of a zero defect program.		
g. Total Productive Maintenance in the Office (efficiency—involvement of the administration in TPM program)		
h. Safety and Environmental Management (establishment of a health, safety and sustainable environmental system)		

Kindly explain your responses to the above, if necessary?

_____

_____

_____

_____

_____

_____

2. What are the 5 key measures that you use within your department each month?

Measured Parameter	**Monthly average value if applicable (include unit of measure)**	**Target value if applicable**

2.1 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

3. Who carries out the following aspects of routine maintenance in your organization? Tick the appropriate box. If not applicable, please indicate as such

Activity	Done by Maintenance Personnel	Done by Operators / Production Personnel
Housekeeping.		
Equipment cleaning		
Protection of components from dirt		
Lubrication		
Equipment inspection		
Setups and adjustments		

1. For the following questions you are asked to express your understanding and interpretation of the Total Productive Maintenance domain.

Please confirm if the following is currently happening in you work environment

a) Autonomous Maintenance?

The best practice of operators taking ownership of their equipment and sharing the responsibility of its maintenance with the maintenance department

Do you agree? Is this currently being practiced in your current work environment?

_____

_____

_____

b) Kaizen – Continuous Improvement?

This denotes improvement through carrying out small, incremental steps improvement steps and continuously questioning and re-questioning the seemingly normal

Do you agree? Is this currently being practiced in your current work environment?

_____

_____

_____

c) In TPM, Operators are expected to carry out certain maintenance activities apart from the normal duties of an operator. Does this practice apply to your organization

i. Yes or No? _____

ii. Justify your answer to the above

_____

_____

_____

_____

_____

d) If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

_____

_____

_____

_____

e) For the following question you are required to reflect on your experiences

1. **Select five reasons why TPM can fail in your organization?**

   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

2. **What challenges can be expected in introducing TPM in your organisation?**

   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

3. **What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section?** (state at least five (5))

   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

Thank you for taking time to share experiences and knowledge by completing this questionnaire.
Please fill this questionnaire on line to a link that will be send to you through e-mail

"Investigate Alignment of Current Maintenance Practices to Total Productive Maintenance (TPM) In One Selected Conglomerates in Gauteng South Africa"

Contact Emmanuel or Teresa on the details below

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APPENDIX C: Responses

C1: Respondents Comments for On Line Survey - Open Ended Questionnaire Sections

RESPONDENT A

Q1 What are the 5 key measures that you use within your department each month? Please state achieved monthly average and then target

1plant availability

2plant utilisation

3energy consumption

4spares cost

5labour cost

Q2 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

1spares availability

2equipment availability

3utilisation

4equipment handling

5energy management

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

It is difficult to rotate employees to other sections as it involves money(grading) issues

Q4 For the following question you are required to reflect on your experiences

4.1 What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? State at least five (5)

Knowledge, team work, support, skills, education

RESPONDENT C

Q1 What are the 5 key measures that you use within your department each month? Please state achieved monthly average and then target

1Time efficiency 25% vs 60%

2Job efficiency related to repeat tasks 35% vs 75%

3Planned maintenance 5% vs 80%

4Safety in procedures 85% vs 100%

Q2 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

1Never enough time to do proper work always time to re-do

2No time to release equipment for menial planned maintenance stoppage.

3It is maintenace's work to clean, we produce.

4It is not our concern.

5If we damage something, you get it fixed

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

Unions should work on their own concerns and not try to do what they are not trained to do. Workers should be trained and accepting of required work.

Q4 What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? (state at least five (5))

1. Production Attitude. 2. Believe that TPM will work. 3. Accept that artisan training is not effective. 4. Know the role of production in equipment usage. 5. Accept that machines can and will fail.

Q5 For the following question you are required to reflect on your experiences

5.1. What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? (state at least five (5))- Management Support -Availability of resources -Training / Skills -good inter Departmental relations –Teamwork

RESPONDENT D

Q1 What are the 5 key measures that you use within your department each month? Please state achieved monthly average and then target

1No. of breakdowns

2Productive hours vs available hours

3Safey stats

4Cost

5Downtime

Q2 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

1Reporting of breakdowns

2Vehicle Operators

3Communication

4availability of spares

5Cost

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

Unions must encourage member to be : 1. committed to TPM 2. undergo all required training 3. improve participation in TPM 4. committed to their jobs and the firm 5. aware of cost implications

Q4 For the following question you are required to reflect on your experiences

4.1 What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? (state at least five (5))

1. committment of management 2. focus of safe production 3. training & development

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

unions are contraditing themself, they work with management and agreed in most issues without consulting they members,by the time of implimention we encounter lot of problems:e.g pyslip and holiday issuas.

RESPONDENT E

Q4 For the following question you are required to reflect on your experiences

4.1 What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? State at least five (5)

communication,training,create clear procedures to be follow, appoint champions both at production and maintenance.

RESPONDENT F

Q3. If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

educate the employees that their work spans beyond what is written on the job description

RESPONDENT G

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

Before we even think of unions, Management should first acknowledge that maintenance is central to production planning. Currently maintenance is still handled like an outside department, similar to a contractor.

RESPONDENT H

Q1 What are the 5 key measures that you use within your department each month? Please state achieved monthly average and then target

1MACHINE DOWNTIME

2MACHINE EFFICIENCY

Q2 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

1MACHINE AVAILABILITY FOR MAINTENANCE

2TIME TAKEN TO REPORT BREAKDOWNS

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

UNIONS SHOULD ENCOURAGE MANAGEMENT TO HAVE A CONTINUOS DEVELOPMENT PROGRAM THROUGH TRAINING FOR EMPLOYEES TO IMPROVE THEIR SKILLS AND HENCE UNDERSTAND THE GOALS OF THE ORGANIZATION.

Q3.1Kindly explain your responses to the above, if necessary?

Even though we highly regard capital equipment acguiring as way of improving the business output and product quality, we still do not regard TPM as a critical tool that can be used to maintain and sustain the capital improvement made.

RESPONDENT I

Q1 What are the 5 key measures that you use within your department each month? Please state achieved monthly average and then target

1Work done

2Money spend

3work to be done

Q2 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

1Production target

2Sales

3Equipment downtime

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

Explain the role that floor employees have in contributing to the success of the organization.

Q4 For the following question you are required to reflect on your experiences

4.1 What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? (state at least five (5))

1. Business growth 2. Skills development 3. Better relationship between management and union 4. Product quality, avoiding rework 5. Better environment for learning

RESPONDENT J

Q1 What are the 5 key measures that you use within your department each month? Please state achieved monthly average and then target

1Plant availability- 49% (52%)

2Mechanical delays-8.0%(8.5%)

3Electrical delays-3.2% (3.0%)

4Roll Shop delays-1% (1.5%)

5Production delays-25% (22%)

Q2 What are the 5 most important measures from other departments that have the greatest influence on your ability to achieve the above mentioned measures?

1Spares availability from suppliers

2Electricity

3Stores supply of spares

4Approvals for orders

Q3 If your organization does have a unionized environment, what role should Unions play in ensuring the success of TPM?

Collaborative and supportive

Q4 For the following question you are required to reflect on your experiences

4.1 What are the current synergies that you think will be make it necessary for implementation of a TPM in your organization or section? (state at least five (5))

We want better production We want better yields Safety is everyones concern We dont want the business to shut

Appendix D Interviews Responses

D1: Interview Template

Interview Questions and Responses:

My name is Emmanuel Mabwe. I am here to interview you on our current maintenance practices in your section as well as to get an understanding of various maintenance practices that are on offer. All responses to this will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions so that I remember what you would have said. Feel free to ask me for any clarification. Thank you for allowing me to interview

Interview Template:

Name:

Role:

Date:

Place:

Time:

Thank you for agreeing to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization?

What are the main functions of your section / department?

What role do you play to achieve these functions?

Maintenance Practices

Do you have a Planned Maintenance Program?

Is there a maintenance policy with clear objectives and set goals visible for all to see?

Who is responsible for breakdown requests?

Who is responsible for maintenance requests?

Who is responsible for spares availability?

How are breakdowns tackled in your department?

How are maintenance issues executed in your department?

What measures do you use to measure your department's performance?

What challenges are you currently facing within your department?

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer.

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain.

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

What areas will need further improvement if TPM is to be implemented?

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

D2: Interview Transcripts

Interview One

Name: A1

Role: Maintenance Foreman

Date: 2014/02/10

Place: His Office

Time: 1030hrs

Thank you for agreeing to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Yes

Background Information

How long have you been with the organization?

I have been with this company for 16 years. I joined the company as a Production Supervisor and after five years I was promoted to the position of Maintenance Foreman for the welding section of the factory. I have been in this position ever since.

What are the main functions of your section / department?

Attending to machine breakdowns. I have two teams of six artisans working on shifts and they are attending to the breakdowns that happen on the machines from time to time.

What role do you play to achieve these functions?

I organize the shift of the guys and also monitor the time keeping. I also organize spares for them by signing requisitions for stores items and placing orders.

Maintenance Practices

Do you have a Planned Maintenance Program?

No, we don't have a Planned Maintenance program. We are busy with breakdowns that its not possible to have time for planning. We have a planner but he is more of a buyer than a Planner.

Is there a maintenance policy with clear objectives and set goals visible for all to see?

No that is not in place but our objective is to clear breakdowns in the shortest possible times.

Who is responsible for breakdown requests?

Normally the Production Supervisor is the one who alerts us for breakdowns.

Who is responsible for maintenance requests?

I do the maintenance requests depending on whether the machine is available for maintenance or not.

Who is responsible for spares availability?

Stores are responsible for ordering maintenance spares.

How are breakdowns tackled in your department?

When we get a breakdown report, the artisan goes to the particular machine and assesses the nature of the breakdown with the operator. In the event that the breakdown is of a catastrophic nature requiring a new shaft to be machined for instance, he reports that to me. This is so that I check the availability of the spare. If the spare is not available, I check if we can machine it quickly enough or if not I check with the Engineer if we can take the spare from other machines that will be on standby. This we normally do if the machine is making a critical commodity that will be required by the customer in the shortest possible time.

How are maintenance issues executed in your department?

We discuss plant issues every morning during our tool box talks. Apart from safety, this is where we discuss plant performance issues and problem areas. Input from artisans help in understanding the plant status and those areas of the plant that needs attention. I forward this information to the Maintenance Engineer who has to organize the ordering of the requisite spares and also ask production to release the machine for maintenance. We normally do the maintenance work during weekends.

What measures do you use to measure your department's performance?

As a Foreman, I have a daily downtime report where I input all the data of the machinery downtime. I trend the breakdown duration, lead time to get the necessary spares and comments on how the breakdown would have been dealt with. Its basically breakdown durations of the 44 machines. I give this information to the Maintenance Engineer as well.

What challenges are you currently facing within your department?

We don't have adequate spares in stock. That is a major problem and with the nature of the catastrophic failures that we have, we end up waiting for weeks to restore a machine back to operating conditions. The situation is very frustrating to the artisans and to me. I end up cannibalizing spares from one machine to the other and this asset stripping is not good for the company. Our stores also lack the basic spares that we need like bolts and nuts and I end up

driving to town to get the basic of items for use. These items are supposed to be in stock but they are not in stock. It is very frustrating.

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

No not at all. I think they are here to break the machines. This is the due to the nature of breakdowns that one can easily see are man made. They call us when there is a breakdown and when you go to the machine, you see that it is damaged due to over tightening of bolts for instance. This has been happening for ages but nobody does anything about it.

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

We haven't started formal discussions on the reasons for these failures but I measure my artisans but the time that they take to sort out a breakdown. This way I ensure that there will be an improvement when the artisan does the job next time. I also tend to compare the shifts and watch out for those that leave jobs for the next shift to finish.

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer.

I will take this as 90% on breakdowns and 10% on maintenance. We don't have a PM program and we are in a fire fighting mode at the moment. This is making it difficult to have a structured maintenance program.

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain.

Not here at all. We have serious industrial relations and Operators are not even happy with the remuneration that they are doing for the current job. I therefore don't see them accepting any extra responsibilities. In any case they would even be happier if the responsibilities are reduced as it stands (chuckles).

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

No, not all. TPM will be a no go area unless if one wants a strike here. While it is a good approach, its not practical mainly because of our strained industrial relations and will not get the necessary buy in.

What areas will need further improvement if TPM is to be implemented?

We need to sort the industrial relations issues first and all things will fall into place.

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Two:

Name: A2

Role: Electrical Foreman

Date: 05/02/2014

Place:

Time:14:00

Thank you for agreeing to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization?

Ans: 3 years 6 months.

What are the main functions of your section / department?

Ans: Electrical maintenance.

What role do you play to achieve these functions?

Ans: Repair machines on breakdown basis and do planned maintenance.

Maintenance Practices

Do you have a Planned Maintenance Program?

Ans: Yes

Is there a maintenance policy with clear objectives and set goals visible for all to see?

Ans: No

Who is responsible for breakdown requests?

Ans: Production Foreman

Who is responsible for maintenance requests?

Ans: Electrical foreman

Who is responsible for spares availability?

Ans: Electrical foreman

How are breakdowns tackled in your department?

Ans: Production submits the breakdown request form to the electrical foreman who will issue it to the artisan to attend the breakdown.

How are maintenance issues executed in your department?

Ans: We have a daily maintenance departmental meeting with all maintenance foremen and the maintenance manager in the morning where we discuss, breakdowns in the plant , maintenance plan and spares required.

What measures do you use to measure your department's performance?

Ans: The number of breakdowns per month, amount of time spent on breakdowns and the time the machines produced without breakdowns , machine efficiency.

What challenges are you currently facing within your department?

Ans: Not enough manpower , the level of skill is very low , planned maintenance program is not being followed because production tends to change their plans the last minute always.

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

Ans: No

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

Ans: Discussing about the breakdowns that occurred as a team and identify the ones that have repeated and come up with ways of improving the way the machines do operate.

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer.

Ans: Breakdown work is 90% because the machines are running both day and night shift and the time we get to work on them is sometimes weekends but since the overtime has been reduced to only 10% per week its very difficult . Maintenance work is 10% .

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain your answer.

Ans: No . The operators will be carrying two responsibilities and they will request that their salaries be reviewed and job description.

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

Ans: Yes . I do think it's a viable maintenance strategy because it will give a sense of ownership to the operators and they will have a better understanding of the operations of the machines that they are working with.

What areas will need further improvement if TPM is to be implemented?

Ans: Training of operators on the safety and basic engineering .

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Three:

Name: A3

Role: Maintenance Foreman

Date: 2014/02/13

Place:

Time: 1030h

Thank you for agreeing to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization? *17 years*

What are the main functions of your section / department: *I am the Maintenance Foreman for Flash Butt welding. I am responsible for maintenance, minor projects and also plant improvements.*

What role do you play to achieve these functions?

I do organize spares, make drawings and also do a bit of design work. I am also involved in scheduled maintenance.

Maintenance Practices

Do you have a Planned Maintenance Program?

They are busy with it and people from Head Office have been on the plant already to try to implement some program. However currently there are no drawings or manuals for the equipment we have most of which is over 30 years old. We have daily lubrication schedules for the plant and daily checking of oil pipes. We also have daily compressor checks where if we note any adverse conditions we call in the contractor to come and rectify. We also do scheduled cleaning of cooling towers and water treatment. Compressors are also serviced after scheduled running times while the cooling towers are done during the December shutdown.

Is there a maintenance policy with clear objectives and set goals visible for all to see?

Uhmm, we try, when we come across minor breakdowns, we go further to carry out visual checks and get the correct information on the status of the machinery. We then alert management of potential problems so that we get the opportunity to rectify before the situation escalates in bigger problems. However the problem is management is always after production and do not give us the machinery on time to rectify these issues.

Who is responsible for breakdown requests?

From production side, but we can ask for maintenance downtime requests if we notice potential problems.

Who is responsible for maintenance requests?

It's me as the Maintenance Foreman and Maintenance Manager.

Who is responsible for spares availability?

Stores is responsible for stock items and I am responsible for non- stock items.

How are breakdowns tackled in your department?

I basically select the guys depending on capabilities and the type of job to be done. This is important because some of the artisans don't have the requisite skills or are not familiar with the machines. I cannot, for instance give a guy like B a hydraulic problem because I know he will take ages to complete. You need the better guy for that, somebody who understands the plant better.

How are maintenance issues executed in your department?

We find the nature of the potential problem through plant walk-about and order all the necessary spares that will be needed. Once all the spares are available we then allocate it to the necessary artisan. After the artisan has completed the job, his handover process involves testing the machine in the presence of the operator and hand it over to the operator for running. He must observe the operation for at least 20 minutes to ensure that the machine is reliable and working in an operable state.

What measures do you use to measure your department's performance?

The main point is to check how long it takes one to finish the job versus a historical standard. I also determine how long the item will run before the next failure and take note of repeat jobs.

Is all this recorded formally?

No, I basically use my own note book. I don't produce any formal reports about this but that is how I do it.

What challenges are you currently facing within your department?

The skills of some of the artisans is poor, even those with a Red Seal certificate. This results in some breakdowns taking too long to solve since some of the artisans fail to do proper trouble shooting and hence rectify issues on time. Further training and skills upgrading will be required. We also don't have enough spares in stock. We don't have drawings or manuals for our aged

equipment and it becomes difficult to do an overhaul since you have to use what you would have removed as a sample. This again makes and overhaul exercise a lengthy process. Fortunately we are doing our own drawings as we go along.

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

No, this is not happening by us. They do not even clean the machines and when you start working they run away. Even when you want to test the machine the operator will not be around to check, they run away.

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

After a breakdown the guy must make a proper drawing of the work done and this record will be an improvement. We also try different types of material and oils in order to improve and this is also to improve your set up.

What ratio of your work is expended on maintenance work and Breakdown work?

Please explain your answer.

70 to 80% breakdowns and the rest is maintenance. It would be nice if its 50% to 50% but then machines are not easily given up for maintenance. The machines are old as well.

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain.

I think they should, I think you can get a guy that wants it and also certain guys who will be against. Certainly people want to learn something. But people will want more money or a higher grade is he gets extra responsibilities.

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

Well the company is trying to do it but at this stage it's difficult. It will be possible if it's done within a 5 year period. It must be done gradually and maybe it might work.

What areas will need further improvement if TPM is to be implemented?

Improve planning and availability of machines for maintenance. Communication between the shop floor and management needs to improve. Machines stand (sic implying machines go on breakdown) due to lack of communication and the need for chasing production tonnages. People will run to the unions if you request one to do more work for no money. So you need to get them on your side.

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Four:

Name: A4

Role: Engineering Manager

Date: 2014/03/12

Place:

Time: 1230hrs

Thank you for agree to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization?

1yr

What are the main functions of your section / department?

Engineering Maintenance (Planned/Unplanned), Project Management, Energy Management

What role do you play to achieve these functions?

Developing planned maintenance strategies, policies and systems plus implementation. Installation and commissioning of new plant, Energy management strategy development and implementation

Maintenance Practices

Do you have a Planned Maintenance Program?

Yes

Is there a maintenance policy with clear objectives and set goals visible for all to see? *It is under construction*

Who is responsible for breakdown requests? *Operations personnel*

Who is responsible for maintenance requests? *Section Engineers*

Who is responsible for spares availability? *Stores department*

How are breakdowns tackled in your department? *Operations personnel raise breakdown requests and submit them to relevant engineering team and artisans are assigned to both troubleshoot and resolve the breakdown*

How are maintenance issues executed in your department? *They are divided into tactical (short term) and strategic (long term). Tactical ones are dealt with at section level while the strategic ones are dealt with at the Engineering Leadership level*

What measures do you use to measure your department's performance? *Artisan Capacity utilization. Plant Availability, Operational Costs Vs Budget, Maximum Demand, Meantime to failure etc*

What challenges are you currently facing within your department? *Skills shortage, budget constraints*

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work? *To a very limited extent*

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures? *Maintenance performance is monitored every week through a measurement matrix that has been developed.*

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer. *Maintenance work 35% breakdown work 65%*

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain your answer. *Not at this stage. There is still a huge gulf between engineering and production. Production teams still believe maintenance is a purely engineering function, theirs is to produce.*

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain. *Yes it will be. The team is currently busy putting in place the building blocks of TPM*

What areas will need further improvement if TPM is to be implemented? *Training and awareness, inventory management, information management systems, performance management*

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Five:

Name: A5

Role: Mechanical Engineer

Date: 16 April 2014

Place:

Time: 08h30

Thank you for agree to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization? *5 years*

What are the main functions of your section / department? *Projects (New & Plant Upgrades)*

What role do you play to achieve these functions? *Project Engineer*

Maintenance Practices

Do you have a Planned Maintenance Program? *Yes*

Is there a maintenance policy with clear objectives and set goals visible for all to see? *There is a maintenance policy but it doesn't seem to be clearly followed*

Who is responsible for breakdown requests? *Production personnel*

Who is responsible for maintenance requests? *Maintenance personnel*

Who is responsible for spares availability? *Maintenance Engineers*

How are breakdowns tackled in your department? *Production notifies the responsible maintenance foreman who raises a job card and plans and executes the repair work.*

How are maintenance issues executed in your department? *Breakdowns are tackled as they get reported and planned maintenance activities are notified to production in advance to have the machine available for maintenance at the planned time.*

What measures do you use to measure your department's performance? *Plant availability, maintenance expenditure monitoring, amount of overtime, percentage of planned jobs completed*

What challenges are you currently facing within your department? *Quality of maintenance work, spares availability, availability of tools and other equipment, poor maintenance budgets, skills shortage, aging equipment with no records, drawings or technical information.*

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is

not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work? *They are not involved at all, they do not even do cleaning or lubrication tasks.*

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures? *Good record keeping and good planning though this is challenged by the lack of dedicated maintenance planners.*

What ratio of your work is expended on maintenance work and Breakdown work? *90% planned maintenance work and 10% breakdown maintenance work*

Please explain your answer. *Because most equipment is at just above 90% availability.*

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain your answer. *Operators wouldn't want to carryout maintenance work because they argue that it is not part of their job descriptions and to resolve that the job responsibilities need to be redrawn.*

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain. *TPM will not be viable because of the inherent culture in the organization and addressing the problems will take a long time and lots of efforts to change the culture in the workforce, especially operators.*

What areas will need further improvement if TPM is to be implemented? *Job descriptions and responsibilities need to be redrawn and get people to agree to the new terms. Both production and maintenance people need training on the principles of TPM and only with a clear understanding will implementation of TPM be possible.*

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Six:

Name: A6

Role: Maintenance Engineer

Date: 12/03/2014

Place:

Time: 1045h

Thank you for agree to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization? *8 yrs*

What are the main functions of your section / department? *Engineering Maintenance (Planned/Unplanned), Project Management, Energy Management*

What role do you play to achieve these functions? *Developing planned and preventative maintenance strategies, policies and systems + implementation. Identifying opportunities for*

process improvements through the use of technology, Installation and commissioning of new plant, Energy management strategy development and implementation

Maintenance Practices

Do you have a Planned Maintenance Program? *Yes*

Is there a maintenance policy with clear objectives and set goals visible for all to see? *It is being developed*

Who is responsible for breakdown requests? *Engineering Foremen*

Who is responsible for maintenance requests? *Engineering Foremen*

Who is responsible for spares availability? *Engineering Foremen and Stores (for routine spares)*

How are breakdowns tackled in your department? *Operations personal raise breakdown requests and submit them to relevant engineering team and artisans are assigned to both troubleshoot and resolve the breakdown*

How are maintenance issues executed in your department? *Maintenance schedules have been developed for sections of the plant and these are executed at plant level. The schedules have been developed in line with OEM and the experience developed from operating the machines. Long term maintenance issues are decided upon by the Engineer and the Foremen.*

What measures do you use to measure your department's performance? *Artisan Capacity utilization. Plant Availability, Operational Costs Vs Budget, Maximum Demand, Meantime to failure etc*

What challenges are you currently facing within your department? *Skills shortage, budget constraints, Capacity constraints which inturn do not allow production to make machines available for maintenance.*

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work? *very limited*.

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures? *Maintenance performance is monitored on a daily and monthly basis by monitoring the downtime and analyzing repeat jobs.*

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer. *Maintenance work40% breakdown work 60% because most of the time production cannot stop to allow Engineering to carry out maintenance due to customer demand.*

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain your answer. *Not at this stage. Mainly because of the skill levels of the operators.*

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain. *Not at this stage we will need to start the building blocks by improving the basic skills of the production operators. From reading and writing and handling tools*

What areas will need further improvement if TPM is to be implemented? *Training and awareness, inventory management, information management systems, performance management. Revamping of the maintenance system as a whole by also putting in place a maintenance software to start capturing the information*

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Seven:

Name: A7

Role: Maintenance Planner

Date: 2014/02/13

Place:

Time: 1030h

Thank you for agree to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization?

I have been with this company for ten years, 7 years as a Fitter and 3 years as a Maintenance Planner.

What are the main functions of your section / department?

I order spares, send spares out for reconditioning and also ensure that we have enough spares to do assemblies. I have also been involved with maintenance of late.

What role do you play to achieve these functions?

I ensure that spares are delivered on time through follow up with suppliers. I also print out inspection checklists for artisans to use on the plant.

Maintenance Practices

Do you have a Planned Maintenance Program?

Yes but it's difficult to follow because of production schedules. We don't get the machines whenever we want to do maintenance activities.

Is there a maintenance policy with clear objectives and set goals visible for all to see?

No there is none.

Who is responsible for breakdown requests?

Production calls for breakdown requests

Who is responsible for maintenance requests?

This is based on plant status reports after inspections done on the machines. I then plan to have the maintenance request catered for by the Maintenance Foreman

Who is responsible for spares availability?

As a Planner I also order spares that are used for direct purchase and I also assist Stores here and there to ensure that they have adequate stocks of spares.

How are breakdowns tackled in your department?

I am not much involved with breakdowns but they emanate from Production and I assist if there are urgent spares that are needed.

How are maintenance issues executed in your department?

I basically have a live maintenance program that emanates from the plant inspections that we carry out weekly.

What measures do you use to measure your department's performance?

I do not have any particular measurements that I am currently using.

What challenges are you currently facing within your department?

I am spending more time buying spares rather than doing maintenance planning. We have the SAP system but we are not able to use it effectively due to lack of training. I have requested that I get trained on SAP but this has been a promise year in and year out. Stores are not supporting us as well because they are not stocking the spares that the plant needs. They are busy expending effort on stock reduction and yet we there are no spares for use in the plant.

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

No the operators are not involved in any maintenance work

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

We discuss breakdowns in the morning engineering meeting with the engineer where major issues that happen in the plant are discussed. Feedback from artisans' reports and also a thorough discussion of technical issues is done during this meeting so that recurrent problems are avoided.

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer.

I think we are spending 75% on breakdowns and 25% on maintenance.

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain.

We have a serious industrial relations problem in this company and I don't see operators and the majority union wanting their members to have more responsibilities without extra money. They take it that maintenance must do their job while theirs is limited to operating the machines.

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

It is a noble idea that will result in improvement of skills for the operators and limit avoidable breakdowns. However it will not be suitable for this place for now due to the industrial relations issue that I have already alluded to.

What areas will need further improvement if TPM is to be implemented?

Our Operators and artisans need further skills improvement training. Currently lack of requisite skills is seriously affecting work delivery and output.

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Eight:

Name: A8

Role: Head of Engineering

Date: 2014/04/15

Place: Head Office

Time: 1200h

Thank you for agreeing to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization?

8 years in the organization but I have been in this role for two years now.

What are the main functions of your section / department?

After management realized that we were having too many breakdowns on various plants, they agreed that it was prudent that we changed the way were running Engineering and maintenance in particular. As such I am responsible in this position to drive the company's maintenance strategy in a sustainable manner. I also realized that were doing different things and measurements were not standardized. Each business unit is doing its own thing and it's really difficult to come up with a consolidated report where you are comparing eggs and eggs, apples and apples so to speak. My job entails establishing standards for maintenance as well as ensuring that each business unit has a Planned Maintenance program that is adding value to the success of the organization.

What role do you play to achieve these functions?

As a team leader for the Engineering function of the organization, I liaise with General Managers of our various divisions and I have already done presentations regarding the direction that we are taking. I have also established a project team around this initiative and it's called the Uptime Improvement team. The team has already been trained with an outside consultant and will basically audit maintenance practices in all the business units based on a certain criteria. This will allow us to draw a base line and know where to start.

Maintenance Practices

Do you have a Planned Maintenance Program?

I have realized that some plants have a maintenance program while others don't have it.

Is there a maintenance policy with clear objectives and set goals visible for all to see?

We are in the process of developing one and this will be used by all the company's business units once its adopted and approved. I am happy that you have come at a time when we are busy trying to improve our maintenance initiatives and I do hope that your project will help us too.

Who is responsible for breakdown requests?

This comes from the Production department

Who is responsible for maintenance requests?

Normally this comes from the respective maintenance section.

Who is responsible for spares availability?

Both the maintenance department and stores are responsible for the availability of spares. I say so because maintenance is there to streamline and offer direction to stores regarding what to keep in stock. Gone are the days when we used to literally have another plant in Stores in the form of stock. Maintenance has to be proactive and the administration of spares should add value to the organization.

How are breakdowns tackled in your department?

We are still in a fire fighting mode where most plants actually wait for breakdowns to happens and shifts are arranged in such a way that artisans attend to breakdowns in the quickest possible way but unfortunately most of the breakdowns will be catastrophic that it defeats the whole purpose of having a fitter on shift which is basically to assess and sort niggling problems.

How are maintenance issues executed in your department?

I am currently not happy with our approach to maintenance as a company. This is the reason why I have decided to go for this uptime project because we are not moving in the right direction. Our records are in shambles and maintenance is in haphazard manner. We have very poor plant availability figures and most of the plants are in a fire fighting mode. Its poor and we got to improve on that.

What measures do you use to measure your department's performance?

Our measures are haphazard too but I would like to ensure that we have Plant Availability and OEE. I want these measures to be consistent throughout the company so that we can easily monitor and measure plant performance. This will lead to the establishment of key bench marks that will make it easier to develop the necessary standards.

What challenges are you currently facing within your department?

Generally there is lack of appreciation of the importance of maintenance across the board. Some senior managers would rather run the plant to breakdown in search for more production rather than having a proper maintenance program. As a result we remain in a firefighting mode. The skill of our artisans is a major concern. They don't understand some of the basics when they are doing trouble shooting. Whereas the nature of our operation demand that one has to understand hydraulics and pneumatics we end up having prolonged breakdowns because of lack of understanding Maybe our apprenticeship program has not given us the results that we require and its important that we have an apprentice curricula that fits the demands of the organization. Our Engineers are also leaving for greener pastures at an alarming rate. Once they pass GCC they don't stay for more than two months with the company. They say we are not paying well.

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

We have not reached that situation. Operators produce and engineering maintains. While it would be very good to have operators maintaining the machines, we have had problems with the unions whenever we want to expand the job scope of individuals because they say such changes must result in change in compensation, including upward reviews wage grades. The company cannot afford such ad-hoc upward reviews.

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

Generally we want our Engineers to take an active role in the analysis and elimination of failures in order to avoid repeats. Root Cause Analysis technique is something we are always advocating for with the General Managers. This will give them ample time to carry out analysis of their plant status. This is lacking at the moment and people are working under pressure and always fighting fires.

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer.

Some of our plants are at 50 50. These are plants that execute shutdown maintenance at various sections of their plants within a certain time period. Other business units, and these are the majority only stop in December and these are where we have problems. They basically run to failure and spend 20% on Planned Maintenance, mostly done during weekends and 80% on breakdowns.

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain.

Like I mentioned before, any additional responsibilities on the part of the operators will trigger a situation where they will need more money. Furthermore, such additional responsibilities will also entail further training of personnel, which in turn breeds expectations. The current skill of the people we have will not take aboard the demands of the program. You cannot force it upon them either. They will not want to take any further responsibilities.

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

What areas will need further improvement if TPM is to be implemented?

Training of personnel, both production and maintenance will be the first step. The necessary buy in will also have to be obtained from the Unions in order for the program to be a success. We definitely need a scientific approach to our maintenance and hopefully we will be able to implement TPM in the near future.

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Interview Nine:

Name: A9

Role: Engineering services manager

Date: January 8, 2015

Place:

Time: 08:35

Thank you for agreeing to participate in this interview. As a brief background to this interview, I am an MSc Mechanical Engineering Student with Wits University and I am investigating the alignment of our maintenance practices to Total Productive Maintenance (TPM). The objective of my research is to determine the adequacies and inadequacies of our current maintenance practices to TPM which in turn will give an indication of the requirements for implementation. All information that you share with me will be confidential and you are free to answer these questions as freely as you can. Please note that I will be taking notes as we go through the questions, and I will also record this interview for use later on.

The interview will be in three sections. I will ask your background information within the company and then ask about your maintenance practices. The final part will be on your understanding of TPM.

If you are in agreement with this can we go ahead and carry out the interview?

Background Information

How long have you been with the organization?

A:- *February 2011*

What are the main functions of your section / department?

A: *Maintenance of: forklifts, cranes, tooling utilized in the ropery, and generating / modification / printing of drawings for other engineering sections.*

What role do you play to achieve these functions?

A*: I am the manager overseeing the forklift (internal transport) maintenance workshop, tooling department and drawing office. I also schedule and maintain records of all statutory load testing and inspections for all the lifting machines on site.*

Maintenance Practices

Do you have a Planned Maintenance Program?

A*: Yes, only as far as the legal requirements demand.*

Is there a maintenance policy with clear objectives and set goals visible for all to see?

A: *Not that I am aware of*

Who is responsible for breakdown requests?

A: *Operations is responsible for ensuring that breakdown requests are written up and handed to the engineering dept.*

Who is responsible for maintenance requests?

A: *Maintenance is discussed between operations and engineering in order for maintenance to be scheduled, and this only occurs when a machine has a defect that does not have to be attended to such as a breakdown.*

Who is responsible for spares availability?

A: *General stores is tasked with that responsibility especially for critical spares, but each engineering section also carries certain spares in order to have better control of availability.*

How are breakdowns tackled in your department?

A: *Forklift breakdowns are reported to the internal transport workshop where my mechanics will attend to the breakdown. Lifting equipment breakdowns are reported to the engineering department personnel responsible for the section who then contact contractors to attend to the repairs. Tooling breakdowns are reported the charge hand and the work is carried out by the fitter on duty.*

How are maintenance issues executed in your department?

A: *The two mechanics that I have in the internal transport come in on Saturdays and the odd Sunday when the forklifts are generally not so busy and will service one or two every so often. This is not an exact science according to hour metre readings at this stage – a list of all our own forklifts is up on a board and maintenance is managed on a rotational basis. Cranes are given a service inspection every six months from which lists of repairs are then made up, and load tested annually. All tooling returned from the factory is cleaned, inspected / serviced and returned to the shelves for correct storage.*

What measures do you use to measure your department's performance?

A: *I measure the condition of housekeeping, the length of time that it takes to get forklifts back to production, and what safety measures are being observed by the mechanics from time to time. Contractual work is monitored for quality, as and when possible, and contractors are held to account for all repairs that they have affected. Tool availability including spares availability is monitored by the charge hand, and if operations have a problem with availability of tooling they will generally contact me to complain. We are now also enforcing recording of all work performed by the fitters in the tool room as part of our uptime improvement project that Scaw Steel Wire Rope is presently embarking on.*

What challenges are you currently facing within your department?

A: *Shortage of skilled supervision that is able to mentor the artisans, as well as a millwright person with experience on lifting equipment who would be able to attend to servicing and repairs*

on our lifting equipment. I also require a design draftsman with some experience to improve deliverability in the drawing office.

Total Productive Maintenance Focus

Total Productive Maintenance is a company-wide maintenance strategy that involves total employee involvement in the execution of maintenance issues and the issue of maintenance is not only limited to maintenance personnel. Production Operators take an active role in the maintenance of their equipment and carry out certain maintenance tasks on their own.

Are Operators ever involved in any maintenance work?

A: *No, we have a hard enough time just getting operations staff to do the regulatory inspections on their equipment properly so that repairs can be effected timeously.*

How does your department ensure that there is continuous improvement in the execution of maintenance duties and eliminating failures?

A: *We have had cause to make modifications to equipment, but mainly for safety reasons rather than to eliminate failures. We are also working on improving service intervals on forklifts to be based on hours that the vehicles are in use, and not months that have passed since the last service.*

What ratio of your work is expended on maintenance work and Breakdown work? Please explain your answer.

A: *In the tool room, maintenance work would typically be 80% of the workload, as there are few breakdowns and the fitters spend most of their time fitting tooling or stripping and servicing tooling. In the internal transport workshop, 75% of all work done is breakdown related as there is a high level of abuse of our forklifts which are mostly over 20years old. The servicing of our forklifts pertains mainly to lubrication and filters as we do not schedule major services for the forklifts at this stage.*

Do you think Operators will want to get more responsibilities of carrying out maintenance work? Please explain your answer.

A: *Yes, if it is at all possible to show them how they can benefit from it.*

Given the current scenario, will TPM be a viable maintenance strategy for the organization? Please explain.

A: *If a sense of pride could be instilled in the workforce in general, they would go a long way just by keeping their equipment clean, which is not the case at this point in time. I think that maintenance by machine operators could be effective with the right attitude on the shop floor*

What areas will need further improvement if TPM is to be implemented?

A: *Workforce attitude will need to undergo a major adjustment, as well as training. Some sort of recognition for good work and clean work area would have to be implemented and monitored by our first line managers.*

Thank you very much for spending your time with me and I am willing to share with you my findings if you are interested.

Appendix E Preventive Maintenance Reports

Preventative Maintenance Neutralization, Pickling & Scrap bailer

Freq. Days	Description	Jan		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
30	C-Hook inspection							905	906	907	908	909	910	
30	Steam heating coils in baths			883			1130	1131	1132	1133	1134	1135	1136	
90	Accumulator on load On load bogey									214			971	
90	Accumulator off leadoff load bogey									217			973	
90	Flash bakers										1138			
90	Stirrers at Neutralization									1149			1150	
90	Hydraulic stations Neutr. & S-Bailer							1152				1153		
90	Lime conveyor		1072									1156		
180	Building structure									1126				
180	Scrubbers										1151			
180	Mono pump in basement											1154		
180	Water softner										2399			
360	Spark tests on rinse baths													439
360	Repair Acid & Coating cranes													882
360	Renew bags in bag house													881
360	Hydraulic power packs													485
1080	Boilers													867
1080	Pressure vessel in Neutralization													869
	Comments													
	Boilers & Pressure vesselsTested shut down 2010 must be retest 2013 December													

Monthly 3 Monthly 6 Monthly Annually 3 Yearly

ENGINEERING

PREVENTATIVE MAINTENANCE MEETING

Minutes of the Engineering Preventative Maintenance meeting held on the 9 April 2014 at 08h00 in Mr [redacted] Office

Chairman:

Attendance:

Apologies:

DEPARTMENTS:

DATE	GENERAL	
2013/07/04	In future A Taljaard must attend this meeting	

ELECTRICAL:

DATE	TASK	TARGET DATE
2014/04/09	Easter (SCB m/s's)-FR10 & FR11 outstanding. Easter-FR2 flipper cranes compressor water supply pumps W/D-in floor conveyor. Easter-Pickling cranes-boiler.	

MECHANICAL:

DATE	TASK	TARGET DATE
GENERAL: 2014/04/09	First Aid Box & Fire done, must sign off.	
WIRE DRAW: 2014/04/09	FR2 & FR3 not done & scale	
GALVANISE: 2014/04/09	Take-up GL6 not done. Must look at transporter.	
PICKLING 2014/04/09	Building not done in Feb. must look at doing in now.	

ELECTRONICS:

DATE	TASK	TARGET DATE
2014/04/09	See extra sheet.	

GARAGE:

DATE	TASK	TARGET DATE
2014/04/09	All in order.	

B FACTORY:

DATE	TASK	TARGET DATE
2014/04/09	Plant is running perfect. To do preventative maintenance, few done must be marked off.	

PROJECT JOB CARDS

DATE	TASK	TARGET DATE

NEXT MEETING TO BE HELD ON
22 MAY 2014 IN MR [illegible] OFFICE @ 08h00

ENGINEERING JOB REQUEST

DATE	DEPARTMENT	MCH	PERSON JOB REQUEST	JOB REQ NO	JOB REQUEST	COMPLETION DATE	RESPONSIBLE
16/04/2010	Garage			5261	Plse repair drain pipe at forklift garage. Pipe pulled out.		
20/04/2010	Wire Draw			4592	Plse manufacture x2 stands (portable) to host pallet and descaling bag as was done refering to job request no:5913		
29/04/2010	Galv			7459	Plse order signs for transporters 4 off and install "No operator interference while transporter is in operation" yellow background		
21/06/2010	Galv			7461	Please supply 3x waste bins paint blue and mark strapping waste, place one at each compactor	30/06/2010	
24/06/2010	Galv			7462	Plse mnf + install steps on the south side of the lead baths GL5 +6 as discussed		
29/07/2010	Rod Yard			4596	Demarcate area under fire alarm button as "no packing" or "keep clear"		
29/07/2010	Rod Yard			4595	Fabricate and fit a barrier in loading area - east to west . Move existing barrier - north to south - one meter south to create walkway to distribution board		
08/11/2010	Scrap balling			4606	Bale loading area must be clearly demarcated		
08/11/2010	Scrap balling			4607	Area to be demarcated for truck drivers during vehicle off loading and loading		
12/10/2010	Neutralisation			4610	increase trench that directs sludge waste/ spillage to effluent.	12/10/2010	
15/11/2010				4611	Plse remove an electrical extension cable running from IT room into Dix Muller's office on the floor, and put in at least two wall plugs in Dix's office.	17/11/2010	
14/02/2011	Weighbridge			4612	Road from Weighbridge has at least three potholes. Big one. Can you please arrange for it to be repaired	12/15/2011	
01/04/2011	Scrap balling			4616	Stephen to fit beams across front of scrap baling machines to avoid operator entering danger area by switching machine.		
08/03/2011	A Factory Desp			6249	Please install three life lines AFI and A Factory despatch	12/15/2011	
31/03/2011	Wire Draw			4614	Please paint a walkway, from medium draw scale to the Die Shop door.	12/15/2011	
31/03/2011	Wire Draw			4615	Please secure Bench legs at Casualty treatment area.	12/15/2011	
25/03/2011	Galv			7465	Please investigate the possibility to manufacture and install platform at the left-off GL5+6 so that the operators are able to reach the casting roller.	12/15/2011	
28/03/2011	A Factory Desp			7851	Move barrier and walkway in Galv Despatch area.		
28/03/2011	Rod Yard			6250	Please design two mobile fleet warning loading/ off loading signs for Rod Yard.	12/15/2011	
04/05/2011	Galv			7466	Please countersink the walk way plates to be lever with the floor as discussed with M du Preez.	5/4/2011	
08/05/2011	A Factory Desp			7852	Chokes for wire coils need +- 60(Angle Iron)	12/15/2011	
16/02/2011	Rod Yard			4613	Kindly demarcate, Paint roof & barricade A "Safety " waiting area for truck drivers while trucks are being off loaded or loaded.	12/15/2011	
16/5/2011	Galv			7469	Please arrange for bundwall to be removed from the Galvoguard store and to be rebuild in store next to it. Sign to be re - arranged as discussed with M du Preez.		
16/5/2011	Galv			7468	Please manufature a set of tension rollers for back tension on high carbon wire.		
28/06/2011	Galv			7470	Please supply and install extra channel on Zinc and lead ash bins. As discussed with M du Preez	5/3/2012	
21/07/2011	Wire Draw			4623	Please make 2 back plates for strapping to host 32mm strapping	12/15/2011	
21/7/2011	Neutralisation			4622	Please manufacture bin/ carrier to host sludge bags in order to be weighed at the weighbridge	12/15/2011	
19/7/2011	Galv			7471	Please install hand rails at GL5+6 compactor as discussed with M du Preez.	12/20/2011	

PREVENTIVE MAINTINANCE & SERVICE 2014

UNIT No	Description	Location	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Planed For	
6222	Harlan Tow Tractor	Rod Yard													30/5	
X00256	Clark CGP 30	Galv														
Y00400	Toyota 2.5 Ton	Ware House														
6221	Harlan Tow Tractor	Dispatch B Fact	1	1												
6310	Clark C500	Engeneering A														
6314	Clark C500	Engeneering B & C		1												
6327	Clark C500	Store				1									27/5	
6328	Clark C500	Engeneering A				1										
6329	Clark C500	Ware House		1											28/5	
6343	Clark C500	Dispatch B Fact				1									30/5	
6344	Clark C500	Spare														
CO 68	Toyota 3 Ton	C Factory													28/5	X
6348	Clark C500	Wire Draw													24/5	X
6349	Clark C500	Dispatch A Fact		1												
6354	Clark C500	Netting														
6366	Clark C500	Dispatch B Fact														
6367	Clark C500	Export A Fact														
6369	Clark C500	Dispatch A Fact														
6370	Clark C500	Dispatch B Fact		1			1								24/5	X
6371	Clark C500	Dispatch B Fact		1												
6372	Clark C500	Nails														
6374	Clark C500	Wire Draw														
6375	Clark C500	AFI		1			1									
6376	Clark C500	C Factory														
6379	Clark C500	Wire Draw														
6381	Clark C500	Galv														
6345	Clark C500	Spare														
6387	TCM 7 Ton	Ware House														
6390	Clark 7 Ton	Wire Draw (Pickling)													1/6	
6391	TCM 10 Ton	Rod Yard														
6395	Clark GPM 17	Galv														
6396	Clark GPM 17	Galv														
6397	Toyota 4 Ton	Ware House		1												
6398	Toyota 4 Ton	Export A Fact														
X 00054	Toyota 2 Ton	Galv														
X 00055	Toyota 2 Ton	Galv														
6230	Flat Tractor	Dispatch A Fact														
6231	Flat Tractor	Dispatch A Fact														

TOTAL DUE	5	11	14	12	18									
TOTAL OUTSTANDING	1	8	0	4	14	0	0	0	0	0	0	0		
CARIED OVER	1	8	0	4										

DUE	0
COMPLETE	
CARIED OVER	0
OUTSTANDING MONTH END	0