

# The impact of Total Productive Maintenance on the manufacturing sector

By

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## CONFIDENTIALITY CLAUSE

15 September 2003

TO WHOM IT MAY CONCERN

RE: CONFIDENTIALITY CLAUSE

Due to the strategic importance of this research it would be appreciated if the contents of this report remain confidential and not be circulated for a period of seven years.

Sincerely,

I.S. Mabunda

## DECLARATION

This research has not been previously accepted for any degree and is not being currently submitted in candidature for any degree.

Signed..........  
Date..... 15/09/2003 .....

This serves to confirm that the work presented in this research is a sole effort of myself with the help of the supervisor allocated to me by the Graduate School of Business, University of Natal.

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## **ABSTRACT**

Maintenance philosophies have evolved over a period of time. These philosophies have evolved from breakdown maintenance to Reliability Centred Maintenance (RCM). By performing proper maintenance on plant equipment, organisations' goals can be achieved. This forms the basis of the Total Productive Maintenance strategy, which aims to support business goals. Total Productive Maintenance (TPM) is based on the integrated manufacturing system approach that includes process control, quality assurance, safety and maintenance.

Some organisations in South Africa have taken an initiative to implement the Total Productive Maintenance program. This research study confirms that organisations that have implemented the TPM program have had increased productivity, reduced costs and improved the quality of their products. Secondly, factors that affect successful implementation of the Total Productive Maintenance program are identified. Through training of all the employees on TPM, encouraging teamwork and systematically implementing the TPM program, the organisations' competitiveness can be enhanced.

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## **Chapter 1: Introduction and the research problem**

### **1.1 Introduction**

Total Productive Maintenance is defined as an attitude, concept and process of continuous improvement in maintenance and manufacturing processes to improve overall equipment effectiveness, operating efficiency, output quality and worker safety (Davis, 1995). Total Productive Maintenance (TPM) has been in existence since the end of the Second World War (Nakajima, 1989). Due to its success within the manufacturing sector around Japan, many organisations around the world have enlisted the help of experts in the field of plant maintenance to assist their organisations in implementing TPM.

The overall goal of TPM is to provide a safe working environment, ensuring production targets are met and quality products are supplied to customers. Although these areas have always been important, TPM, as opposed to other initiatives such as Predictive Maintenance or Preventative Maintenance, seeks to provide a holistic and more integrative approach to running and maintaining plant operations.

The beginning of post-apartheid era marked a turnaround for most South African businesses. As a result of falling trade barriers and the lifting of trade sanctions against South Africa, many multinational corporations resumed their operations in South Africa. As a result, local companies have had to improve their operations to become more competitive. This resulted in many South African companies expanding their operations across South African borders as well as acquiring similar businesses overseas. Also, these organisations still have to find ways to defend their local share of market and make it difficult for foreign companies to enter the local market.

To meet these challenges, organisations in car manufacturing industry as well as paper making industry have implemented Total Productive Maintenance, to improve productivity. The implementation of TPM has however brought mixed fortunes to some organisations in terms of return on investment.

This is a result of the fact that the TPM program was not properly implemented. As a result, there is a need to assess whether or not TPM does affect the performance of the organisations, with specific emphasis on organisations' productivity, quality and employee safety.

## **1.2 Background of the research**

Maintenance plays a significant role not only in determining the availability of the plant and equipment, but also in determining the availability of the final product. Total productive maintenance brings maintenance into focus as a necessary and vitally important part of business. Nakajima (1989, p.2) noted "the key innovation of TPM is that equipment operators perform autonomous maintenance i.e. basic maintenance on their own equipment". This includes tasks such as lubrication and daily checks on plant equipment.

The concept of TPM includes both the Preventative Maintenance (PM) and Reliability Centred Maintenance (RCM). Preventative Maintenance is based on the premise that performing equipment overhauls at predetermined intervals could prevent equipment failures. This entails establishing a total system of productive maintenance for life of equipment and establishing standards for condition based maintenance. It also includes the respective responsibilities of operating staff and maintenance staff (Pycraft et al. 2000). On the other hand, Reliability Centred Maintenance aims to maintain all equipment to a similar level, based on the consequence of failure.

TPM sees maintenance as an organisation wide issue, which is carried out by all employees through small group activities (Pycraft et al. 2000). The most important goal of TPM is that it seeks to maximise equipment effectiveness and minimise equipment maintenance cost. This is achieved through company wide efforts to eliminate six big losses that reduce equipment effectiveness (Nakajima, 1989). These losses are due to equipment breakdowns as well as set-up and adjustment time; which contribute towards downtime losses. Reduced speed as well as idling and minor stoppages contributes towards speed losses. Defects and rework as well as reduced

yield between machine start-up and stable production contribute towards defect losses.

In this study, Total Productive Maintenance in Sappi Kraft–Ngodwana Mill and SABMiller–Polokwane Brewery is researched to ascertain the effectiveness of the TPM program. Sappi Kraft–Ngodwana is a paper manufacturing company that is a division of Sappi Limited. This organisation has implemented TPM since 1997. SABMiller–Polokwane, manufactures alcohol based consumer products. This organisation has implemented TPM since 1994.

### **1.3 Motivation for the research**

Despite the fact that some organisations have implemented TPM, safety incidents are on the increase and quality defects are affecting productivity of these organisations. Also, production targets are not being achieved due to equipment downtime. This research aims to establish whether or not there is a relationship between TPM and the safety of employees, the quality of products and productivity of organisations. Thereafter, the research will identify factors that impact on the successful implementation of TPM.

### **1.4 Value of the project**

Total Productive Maintenance has become part of manufacturing organisations' strategy to gain competitive advantage. Due to high costs associated with its implementation, it is important for these organisations to realise returns on investment. To achieve this, it is necessary to conduct a study to identify possible pitfalls that can lead to TPM's failure and devise some means to address these.

Having accomplished the above, it is believed that equipment performance will improve considerably through the correct use of TPM tools. Consequently, the production targets will be reached.

## **1.5 Statement of the research problem**

What impact does Total productive maintenance (TPM) have on the manufacturing sector? Does TPM influence machine availability and plant efficiency? Do organisations that have implemented TPM achieve or exceed their production targets and product quality? Does TPM have any effect on employee safety?

## **1.6 Objectives of the study**

Despite the support of senior management in the implementation of TPM and subsequent training, machine breakdowns continue to occur more often. Added to this, injuries are more prevalent and production targets are missed a on regular basis.

### **1.6.1 The following objectives are relevant to this study:**

- To determine whether the productivity of organisations can be enhanced through the implementation of TPM.
- To establish whether TPM has any effect on the safety of employees.
- To assess whether or not TPM improves the quality of organisations' final products.
- To identify factors which may influence the successful implementation of TPM.
- To develop a strategy that could help with the implementation of TPM and ensure maximum benefits are derived thereof.

The outcome of this research is aimed at ensuring that organisations (including SABMiller-Polokwane and Sappi-Ngodwana) that have implemented TPM get the value out of the Total Productive Maintenance program.

### **1.6.2 Hypothesis**

- Without implementing the Total Productive Maintenance program, organisations can not achieve increased productivity.
- Organisations that have not implemented the Total Productive Maintenance program have lower equipment efficiency and poor plant availability.
- Total Productive Maintenance improves the quality of organisations' products.
- Employees' exposure to safety risk is greatly reduced through TPM.

### **1.7 Research Methodology**

All the organisations in the manufacturing sector that have implemented Total Productive Maintenance in South Africa form the sampling frame for this research. However, due to time constraints, only two organisations will form part of the sample. The one organisation is Sappi Kraft, Ngodwana Mill and the other organisation is SABMiller, Polokwane Brewery. The subjects of this research consist of production managers, maintenance managers, engineers, production operators, artisans (fitters, electricians, millwrights and instrument mechanics), technicians and TPM facilitators.

This study is a cross-sectional research design. Data will be obtained from the questionnaires. A statistical software package will be used to analyse this data. Frequency distributions will be used to confirm statistical inferences i.e. to confirm the hypothesis. Once data is analysed, the necessary conclusions and recommendations will be made based on the results obtained.

### **1.8 Limitations of the Study**

The fact that there are only two organisations under consideration implies that this sample may not be sufficiently representative of all the factories that have implemented TPM in the manufacturing sector. Secondly, there are other

initiatives that have been undertaken the two organisations under consideration. These initiatives can influence productivity, quality and safety. These initiatives include the Total Quality Management or the ISO14001 programs and have not been considered in this study.

## **1.9 Structure of the study**

This research project is structured as follows:

**Chapter one:** Introduction and the research problem. This section lays down a brief background of the research problem and the objectives of this research project.

**Chapter two:** Literature review. This chapter provides literature review on Total Productive Maintenance (TPM) as well as other related subjects. This includes related aspects of operations management that link closely with TPM.

**Chapter three:** Research design and methodology. An analysis of the research methodology to be followed in this research project is detailed. The sampling method used in this research is discussed as well as how the questionnaire will be structured. The statistical procedure to be used for manipulating data acquired from the questionnaire is also outlined.

**Chapter four:** Results of the survey. In this chapter, an analysis of data acquired from the research instrument is performed. This data is used to confirm or validate the statistical inferences.

**Chapter five:** Conclusions and recommendations. Conclusions are drawn based on the research findings and the recommendations are detailed for consideration in chapter five.

**Bibliography:** All relevant literature sources used in the report are listed in this part of the report.

## **Chapter 2: Review of literature**

### **2.1 Introduction**

Total Productive Maintenance is a maintenance strategy that forms part of the company's overall business strategy. This section examines the basis of TPM with the aim of establishing a relationship between TPM and other maintenance philosophies. This section also looks at how TPM can support business objectives by establishing a relationship between TPM and the organisations' strategy.

### **2.2 An overview of maintenance**

#### **2.2.1 What is maintenance?**

Maintenance is concerned with developing tasks and actions to prolong the productive or useful life of the equipment (Blann, 1997). These tasks or maintenance schedules are carried out on regular (planned) basis to ensure that equipment is available to meet production requirements. This involves developing documentation that will ensure that these tasks are carried out correctly and consistently. In an industrial environment, the role of maintenance has become an integral part of the overall profitability of many businesses. Modern maintenance techniques now have the potential for significantly increasing the company's competitive advantages in the global market.

#### **2.2.2 Why perform maintenance?**

There are various reasons why maintenance should be performed on the plant or process equipment. Maintenance is performed to fulfill the legal requirements of the Occupational Health and Safety Act. This is aimed at providing a safe working environment for the employees. On the other hand, the employer or the company also has a social responsibility to provide a safe working environment for the company's employees. This is achieved through

utilising appropriate maintenance techniques and implementing maintenance programs designed to eliminate failures that can have safety consequences (Sappi, 2001).

Another important reason for performing maintenance is that plant and equipment that are not maintained correctly wear out prematurely. This premature wear-out has cost implications that can be associated with the replacement of the equipment. By implementing an appropriate maintenance program it is possible to extend equipment life and therefore reduce the cost of repair. Additionally, unplanned breakdowns impact on the company's ability to produce the final products. Effective maintenance tasks allow equipment to be repaired before it fails and therefore avoid the cost of uncontrolled failures and the possible loss of revenue.

## **2.3 The basis of Total Productive Maintenance**

TPM evolved from various maintenance philosophies and improvement strategies that have been used in different industries. These include World Class Manufacturing (WCM), Total Quality Management (TQM) and other initiatives. Philosophies that have contributed largely towards the development of TPM are the Preventative Maintenance and the Reliability Centred Maintenance.

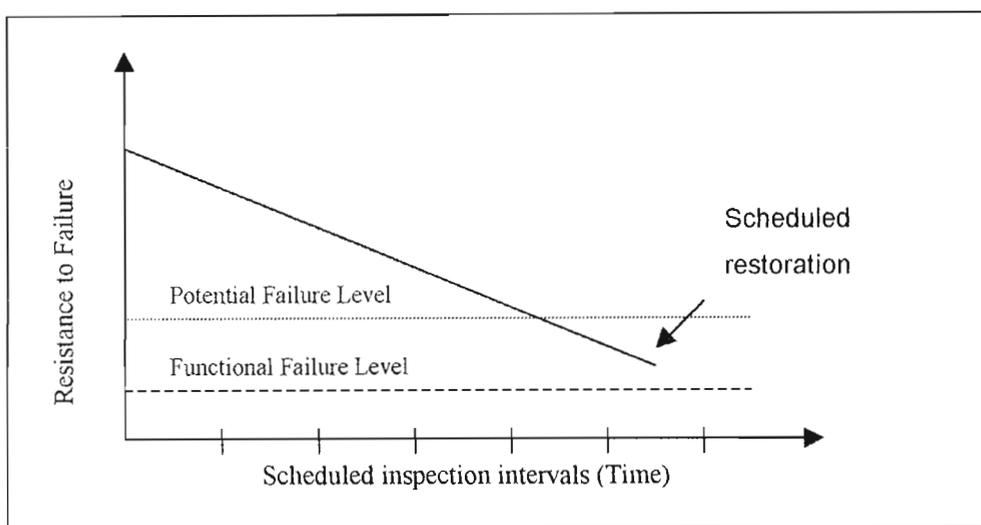
### **2.3.1 Preventative Maintenance**

The first generation maintenance was performed purely on a breakdown basis. Machines or plant equipment were operated until such time when they failed, after which the repairs were then effected. Under these maintenance practices, there was no knowledge of the failure process. As the demand for goods increased, the supply of industrial manpower dropped dramatically. The result was increased mechanisation and automation. By the 1950's, machines of all types were complex and industry was beginning to depend on them. As this dependence grew, reliability and availability of plant equipment came into

focus. This led to the idea that equipment failure should be prevented, which in turn led to the concept of Preventative Maintenance.

With Preventative Maintenance, equipment overhauls are done at fixed intervals (see figure 2.1). This is based on the fact that there is a well-defined life span before equipment failure can occur (Sappi, 2001). This age can be defined in time or usage figures, i.e. the x-axis in figure 2.1.

**Fig 2.1 Equipment failure process**



**Source: Sappi Management Services, 2001, *Maintenance Management Handbook*, p.37**

From the graph above, when a machinery or equipment starts operating, it has a fairly high resistance to failure. Over a period of time, this resistance to failure will decrease. At some point, if no action is taken to correct the situation, the equipment will fail. The point where this happens is called the Functional Failure Level. The Potential Failure Level represents a point when the equipment starts giving some indication or signs that the machine is in the process of failing. The role of Predictive Maintenance is to be able to detect this point before the Functional Failure Level is reached. Preventative maintenance is then performed to avert the imminent failure. By so doing, the resistance to failure can be restored to its original level.

To detect the point of Potential Failure, equipment condition monitoring techniques are used to assess the state of the plant equipment. Through the use of these condition-monitoring tools, failure patterns can be easily identified. These patterns are used to effectively predict eventual failure with some degree of accuracy over time. The condition-monitoring tools include vibration analysis and lubrication (oil) analysis amongst other tools.

### **2.3.2 Reliability Centered Maintenance**

According to Kennedy (2002, p.3) Reliability Centered Maintenance (RCM) is defined as “a structured logical process for developing or optimising the maintenance requirements of a physical resource in its operating context to realise the inherent safety and reliability levels at minimum cost”. RCM uses a rigorous framework to identify all the potential ways an asset can fail to perform its intended function. This approach combines different techniques to maximise equipment reliability in the most economical way. These techniques include Preventative Maintenance as well as condition based (Predictive) maintenance.

Reliability Centered Maintenance provides the necessary tools to determine which plant equipment should be maintained. It also looks at what necessitates the maintenance of that particular piece of equipment and how the equipment should be maintained (Blann, 1997). Because RCM integrates the failure process, it enables maintenance personnel to select maintenance tasks that will slow down the failure process. Alternatively, RCM allows maintenance personnel to perform tasks that will anticipate a breakdown before it occurs, i.e. before reaching the Functional Failure Level in figure 2.1.

Blann (1997) notes that the use of RCM requires that failure modes and the consequences of failure be identified. This is accomplished through the use of history, risk analysis and economic considerations. These are used to identify the most cost effective methods or strategies to reduce the consequences of failure.

Kennedy (2002) advocates that RCM is a methodology that balances the resources being used with the required inherent reliability based on the following precepts:

- A failure is an unsatisfactory condition and maintenance attempts to prevent such conditions from arising;
- The consequences of failure determine the priority of the maintenance effort;
- Equipment redundancy should be eliminated, where appropriate;
- Condition-based maintenance tactics are favoured over traditional time-based maintenance methods; and
- Run-to-failure is acceptable, where warranted.

RCM uses a logic diagram known as the MSG-3 that was developed and used extensively in the aircraft industry (Sappi, 2001). The origins of the decision or logic diagram started when a steering group was formed to oversee the development of the maintenance on the Boeing 747. This steering group was known as the maintenance steering group. The guidelines that were developed became known as MSG-1 (Maintenance Steering Group–model 1). Over a period of time, MSG-2 and then MSG-3 followed the original MSG-1 logic diagram. The MSG-3 decision logic forms the basis for analytical decision logic in use within the Sappi Group and SABMiller. This decision logic is primarily used to develop maintenance schedules. An illustration of the decision or logic diagram is shown in appendix 2.

From the decision logic, by applying a progressive logical approach on all the maintenance significant items, a cost effective maintenance plan is developed. Consequently, this model identifies the relevant maintenance tasks. These tasks are performed at the appropriate maintenance inspection intervals, as illustrated in figure 2.1.

## 2.4 What is Total Productive Maintenance?

The abbreviation TPM is originally known to stand for Total Productive Maintenance. It is now used to describe a variety of words. These include Total Process Management, Total Productive Manufacturing and Total Productive Mining. Irrespective of how the term is used, the underlying principles of these manufacturing strategies are based on the Total Productive Maintenance principles.

Total Productive Maintenance (TPM) was developed in Japan to support Lean Production and World Class Manufacturing (WCM) techniques (Nakajima, 1989). TPM has developed over the years since 1970 when it evolved at Nippon Denso, a major supplier of the Toyota Motor Company. TPM combines principles and practices of quality management with equipment management i.e. equipment defect prevention. Essentially, TPM is concerned with the fundamental rethink of business processes to achieve improvements in cost, quality, speed and delivery. It promotes changes that include multi-skilling of the workforce, empowerment of employees and promoting a culture of continuous improvement.

Three key principles underpin TPM (Hartman, 1992):

- (i) Workplace ownership: Area based teams create a sense of ownership while allowing flexibility through multi-skilling. This eliminates lack of care from employees, which is the root cause of poor equipment performance and failure.
- (ii) Continuous improvement: An environment is created whereby all employees participate in formal improvement activities. This is achieved through area-based teams and cross-functional teams (multi-disciplinary teams).
- (iii) Holistic measurement: An entire picture of equipment performance can be observed through measuring the Overall Equipment Effectiveness (OEE). This looks at all the losses associated with product quality, machine run rates and plant availability.

These principles are core determinants for the effectiveness of the Total Productive Maintenance program. This will be verified in chapter 4 where the findings of this research study are discussed in relation to how effective these principles have been implemented.

#### **2.4.1 Workplace Ownership**

The implementation of the Total Productive Maintenance program requires a fundamental shift in attitude from both the operations and maintenance personnel. That is both the operations and the maintenance disciplines must be responsible for equipment performance and productivity. The TPM program incorporates in it accountability by empowering individual employees and cross-functional teams to drive the program in the right direction.

One of the cornerstones of TPM is the use of operators to perform autonomous maintenance on the plant equipment (Davis, 1995). Autonomous maintenance is concerned with operators performing basic maintenance functions on plant equipment. This includes cleaning, lubrication, inspection, adjustment and setup of the machines. By performing these light duties, operators are much closer to both the process and equipment. At the same time, multi-skilling is achieved while the operators get an opportunity to learn more about the equipment. This empowers operators to easily detect abnormal conditions in the plant as they occur. By so doing, employees gradually begin to gain a sense of ownership over the product, the process and the plant equipment.

#### **2.4.2 Continuous Improvement**

Through small group activities i.e. the Small Business Units (SBU's) and Multi Disciplinary Teams (MDT's), all employees participate in making and implementing improvement suggestions. This creates a sense of ownership amongst the employees. This also allows cross-pollination of ideas amongst participants in these cross-functional teams.

Because operators are closer to the process, they become aware of areas that impact largely on process inefficiencies i.e. bottlenecks (Hartman, 1992). By identifying such areas of improvement, maintenance is then in a better position to assess alternatives that may be implemented to eliminate such process bottlenecks. One way to identify these bottlenecks is through the use of Overall Equipment Effectiveness (see section 2.4.3). By measuring and monitoring the Overall Equipment Effectiveness, teams are encouraged to initiate improvement ideas on a continuous basis. Hartman (1992) suggests that as a consequence of this, the TPM program is an ongoing process of continued improvement supported by all team members. Added to this, a spirit of teamwork is created amongst team members. These are fundamental requirements for a successful TPM program.

### **2.4.3 Measuring the performance of the plant**

A principal measurement that is used in TPM is called the Overall Equipment Effectiveness (OEE). This measure incorporates availability of plant equipment, performance rate and the quality of products to address all losses related to the equipment (Kennedy, 2002). A key objective of TPM is to cost effectively maximise the Overall Equipment Effectiveness. This is achieved through the elimination or minimisation of all forms of waste. The reasoning behind measuring equipment effectiveness is that in order to control losses; there is a need to measure and quantify them. By measuring the OEE, it is possible to tie all the machine losses to the three variables that can be measured. These variables are Availability (Time), Performance rate (Speed) and Yield (Quality).

#### **2.4.3.1 Availability**

This is the time that the equipment is available for production. For instance, in a continuous manufacturing environment, the machine is supposed to be available for production 24 hours per day.

Therefore all availability calculations are based on this period. Availability of the machine is determined by:

- Breakdowns or loss of throughput due to equipment malfunction.
- Set-up and adjustment time, which may result from change from one product type to another.

#### **2.4.3.2 Performance rate**

This is the speed that the machine runs at, sometimes referred to as the run-rate or machine capability. This is determined by:

- Idling and minor stoppages.
- Reduced speed due to discrepancies between designed and actual speed.

#### **2.4.3.3 Quality**

This is a measure of the percentage of product that is in specification. This is determined by:

- Defects in process and rework.
- Defects that occur as a result of reduced yield between machine start-up and stable production.

The following equation is used to calculate the Overall Equipment Effectiveness:

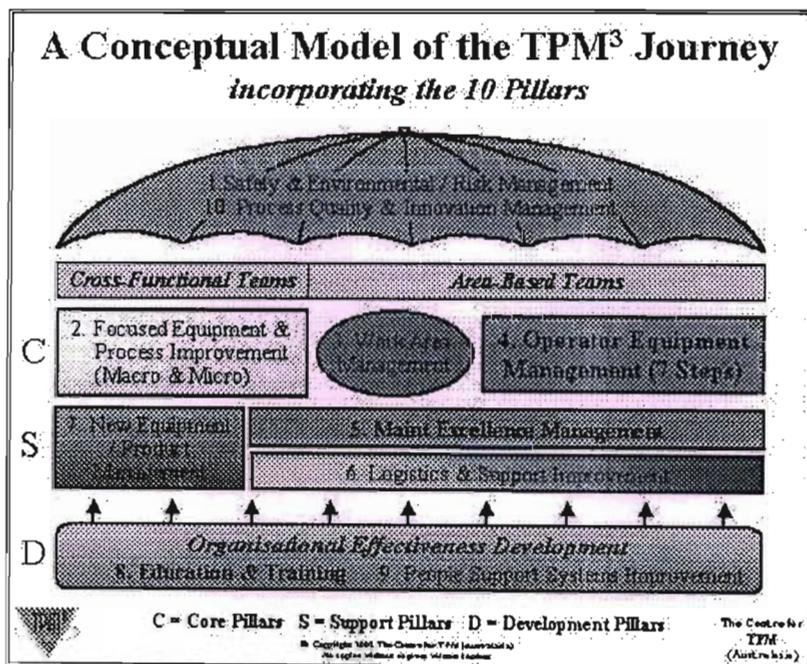
OEE = Availability x Rate x Quality, This is expressed as a percentage

As can be seen, this equation takes into account all forms of major equipment losses. Therefore by correctly measuring these losses, it is possible to put measures and controls in place to eliminate or reduce these losses. Ultimately, these losses impact on the profitability of the organisations.

## 2.5 The pillars of Total Productive Maintenance

Originally there were five activities of Total Productive Maintenance that are now referred to as the first generation TPM. This first generation TPM focussed on improving equipment performance from an equipment perspective. The second generation TPM focused on improvements in production scheduling practices. This was mainly as a result of lost opportunities that were a direct result of poor production planning. Recently, the third generation TPM has evolved out of the necessity of improving people support systems and work area management. The third generation TPM is now called the TPM<sup>3</sup>, Figure 2.2 illustrates a conceptual model of the third generation TPM.

Fig 2.2 Conceptual model of the third generation TPM



Source: Kennedy R, 2002, *What Really is TPM<sup>3</sup> (Australasian 3<sup>rd</sup> Generation TPM)?* p. 8.

From figure 2.2, under the Focused Equipment and Process Improvement, the cross-functional teams (MDT's) are formed. These include members from both maintenance and production disciplines. By having these teams focusing

on reducing equipment and process losses, opportunities are identified. This results in significant improvement in Overall Equipment Effectiveness. This way, a relationship amongst the group members is also built.

The work area based teams (SBT's) are also responsible for initiating formal improvement activities. One important role that is fulfilled by these teams is the implementation and the sustaining of the 5S philosophy. This philosophy focuses on the effective workplace organisation and standardised work procedures. Its aim is to simplify the work environment, reduce waste and non-value adding activities while improving quality and workplace safety. Based on the lean manufacturing principles, which tie closely with TPM, the 5S philosophy is made up of different elements. These include: sort (seiri); set in order (seiton); shine (seiso); standardise (seiketsu) and sustain (shitseku).

The Operator Equipment Management pillar is about using the operators to ensure that equipment is well looked after. Section 2.4.1 explains this in more detail. The Maintenance Excellence pillar looks at what needs to be put in place to improve the processes and machine capability. By assessing the separate elements that contribute to an effective maintenance program, it is possible to identify areas of improvement and put in-place action plans to address them.

Another important aspect of the TPM program is that TPM relies on staffing an organisation with competent people (Pycraft et al. 2000). For this to be accomplished, a significant commitment to education and training is required. Introducing training programs that will allow employees to acquire new skills that are related to their jobs is one way to achieve this. It is also important to impart acquired skills to new employees. Other initiatives that have been undertaken by some South African companies of late is the introduction of the Adult Basic Education and Training (ABET) program. This is as a result of low skills levels in the South African manufacturing and the mining sectors. It is also important that the employees, who are ultimately the custodians of the Total Productive Maintenance program, should undergo a TPM specific

training. This will give them some understanding as to what the program seeks to achieve.

All in all, these pillars are aimed at maximising capacity, productivity, quality, safety, morale and overall profitability of the organisation.

## **2.6 TPM and the organisations' strategy**

Given that requirements for resources is high for implementing a Total Productive Maintenance program that bears fruit, what seems to be the motive behind going the TPM route for organisations? The fundamental issue at this point is to address how TPM supports business objectives to an extent that it contributes towards the bottom line results.

Total Productive Maintenance does not directly contribute towards the financial objectives. Davis (1995) indicates its primary aim however is to enable the organisations to improve their competitiveness. This is achieved through: producing quality products in a cost effective way, having motivated employees and making small improvements on a continuous basis that add value to the final products.

### **2.6.1 What prompts organisations to implement TPM?**

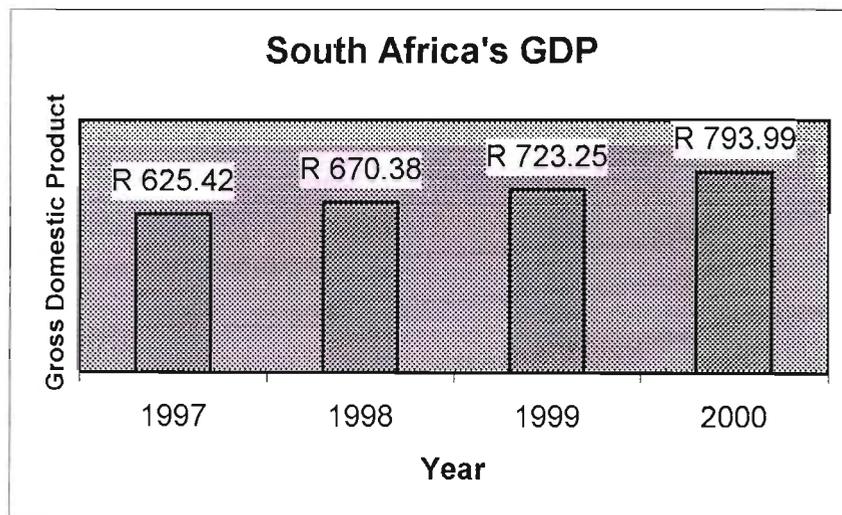
Various factors have contributed towards changing the manufacturing industry. These factors have made the industry to become very competitive and hence the need for TPM strategy.

#### **2.6.1.1 Demand for South African products**

The growth of the South African manufacturing sector has been phenomenal in the past decade. This is in-terms of volumes of goods produced and growth in the number of manufacturing facilities to a certain degree. This growth has been as a result of companies' product demand rising for several reasons.

The one reason is the growth of South African population, which also directly impacts on the demand of local products. Another reason is the relatively low strength of the South African currency (Rand) as compared to other currencies, for instance the U.S. dollar. This has made South African products relatively less expensive from the international buyers' perspective. As a result, the demand for local products has increased due to the low value of the South African currency. On the other hand, South African consumers have become more conscious of product quality.

**Figure 2.3 South Africa's GDP growth**



**Source:** <http://www.gov.za>

These factors have had an influence in the growth of the manufacturing sectors' throughput, Gross Domestic Product (GDP). It can be observed from figure 2.3 that the growth of GDP (values in billions of Rands) has been fairly steady between the years 1997 and 2000. In the same period, the manufacturing sector's GDP rose from R 124.6 billion to R 148.9 billion ([www.gov.za](http://www.gov.za)).

### **2.6.1.2 Trade liberalisation**

The post-apartheid era has also had an effect on the competitiveness of the South African manufacturing industry. This is as a result of lifting of the sanctions against South Africa. According to Hill (2003, p.139) "free trade refers to a situation where a government does not attempt to influence through quotas or duties what its citizens can buy from another country, or what they can produce and sell to another country". This situation has contributed towards increasing the amount of transactions between South African producers and international customers. On the other hand, South African consumers have found themselves with a wide selection of products made from overseas to choose from. Thus deregulation of trade barriers has benefited the South African consumers.

Secondly, as a result of trade liberalisation in South Africa, there has been a considerable increase in foreign direct investment (FDI). For instance, FDI increased from an average of just \$22 million annually between 1988 and 1993 to a peak of 3.8 billion in 1997 (Hill, 2003). Many multinational corporations such as Kodak have since returned to South Africa. This is after their exit due to trade restrictions that were imposed against South Africa as a result of the apartheid regime. The privatisation of state owned assets has also had a positive influence on the rise in FDI.

Hollensen (2001, p.257) notes that "exporting is preferable to licensing and FDI as long as transport costs are minor and tariff barriers are trivial". Due to the fact that many multinational corporations are based overseas, transport costs are substantial, depending on the value to weight ratio. Consequently, many multinational corporations such as BMW have local production facilities. These factors have to a large extent made the South African manufacturing sector fairly competitive.

### **2.6.1.3 The effect of the competitive environment**

The environment in which an organisation conducts its business has a considerable influence on the sustainability of business. Therefore both the company's external and the internal environment will ultimately determine the choice of an organisation's strategy.

According to Thompson and Strickland (2001, p.73), "factors that shape an organisation's external environment include the economy at large, the population demographics, societal values and lifestyles, technological factors and governmental legislation and regulation" (see section 2.6.1.2). An industry's economic features are important because of the implications they have for organisations' strategy. For instance, in an industry where the level of economic development is high, it would be fairly easy for an organisation to integrate either vertically or horizontally. This is necessary to realise economies of scale in purchasing, manufacturing, transportation, marketing or advertising i.e. throughout the value chain of the organisations' activities.

A valuable tool used for assessing the organisations' macro-environment is Porters five-force model. As noted in preceding sections, the steady rise in demand for local goods and services and trade liberalisation has intensified the rivalry among competing sellers. This can be attributed partly to the fact that South Africa being a developing economy, demand for commodity products is high. Also, there are several equal size competitors that are constantly challenging each other for a market leadership position. Another factor to consider is the competitive pressures that stem from buyers bargaining power. The fact that consumers have a wide variety of products to choose from increases the bargaining power of buyers. Similarly, there is an ever-present threat of substitute products amongst industry participants. This has also increased the bargaining power of buyers.

A company situation analysis provides means to evaluate an organisations' resources and competitive capabilities. It is possible to assess how well a company's strategy is working as well as what the company's resource strengths and weaknesses are. This is achieved through the use of Strength Weakness Opportunities and Threats (SWOT) analysis (Thompson & Strickland, 2001). Clearly, many South African organisations were previously protected in a sense that competitive pressures were minimal. Some of these companies are state owned monopolies that were never previously exposed to competitive challenges. As a result, production inefficiencies were common in the manufacturing sector. Therefore an analysis of the organisations resources and capabilities has provided a basis for all organisations to review their strategies in order to compete effectively in this new era.

#### **2.6.1.4 Strategic alliances and acquisitions**

Some organisations have resorted to strategic alliances and acquisitions. This is in response to the increase in demand for goods and services from both local and international markets. This is also as a result of the increase in competitive pressures caused largely by the deregulation of trade. According to Thompson and Strickland (2001, p. 172) "through the use of strategic alliances and partnerships, companies are able to complement their own strategic initiatives and strengthen their competitiveness in domestic and international markets". Through strategic alliances, a company acquires capabilities and valuable resources that it could not otherwise obtain on its own. In so doing, organisations are able to bypass the comparatively slower and capital intensive process of building one's capabilities internally to access new opportunities.

By acquiring other companies, an organisation is able to fill resource gaps. The acquisition of another company may lead to stronger technological skills, better competitive capabilities and more attractive line-up of products. Added to this, an organisation attains wider geographic coverage and greater financial resources (Hollensen, 2001). These can be used to invest in R&D, add capacity, or expand into new areas. Moreover, economies of scale that

may arise as result may provide cost saving opportunities which may result in below average costs per product. Economies of scale arise whenever activities can be performed more cheaply at larger volumes as well as the ability to spread out costs over a greater volume (Thompson and Strickland 2001). This is another reason why some South African companies have been involved in acquisitions and strategic alliances.

This trend is evident in the two organisations that are under consideration in this research study. Recently, South African Breweries has acquired the second largest brewer in North America, Miller Breweries. It is now known as SABMiller and it is one of the largest brewer by volume in the world. On the other hand, the SAPPI group has manufacturing facilities in Europe and Asia, which it has acquired over the last decade. Thus South African manufactures realise the need to diversify their businesses to related industries. As a result, these organisations are in a better position to compete both locally and internationally. This is due to their resource strength and synergies that arise from strategic alliances.

### **2.6.2 The Total Productive Maintenance strategy**

From the analysis above, the following is evident: there is an increase in the number of manufacturing facilities owned by local companies. Also, the consumers' preference for quality products and the competitive pressures have increased. Therefore it has become of utmost importance to consistently meet customer requirements. This has necessitated the requirement to standardise on the manufacturing practices and processes. As a result, companies have reviewed their strategies to meet the new challenges. This is primarily aimed at ensuring cross-business fits along the value chain i.e. in research and development, in supply chain activities and in manufacturing activities. Total Productive Maintenance is a manufacturing strategy that has been chosen by the Sappi group and SABMiller. This manufacturing strategy together with the relevant marketing strategies aligns to support the business strategy.

The Total Productive Maintenance can be seen as the manufacturing strategy that has been chosen to ensure that all manufacturing activities are performed to similar standards across all international business units. This initiative allows, through the experience curve effects, imparting of skills from one business unit to another. Through the use of Best Operating Practices, employees are able to move from one business unit to another with little requirements for re-training. Nestle, a Swiss based company with subsidiaries throughout Southern Africa, has recently introduced Global Business Excellence (GLOBE). This initiative is also aimed at standardising its manufacturing activities ([www.nestle.com](http://www.nestle.com)). For a review of Sappi's TPM objectives and principles, see appendix 3.

## **2.7 Conclusions**

The overall aim of Total Productive Maintenance is to support business objectives. A lot of emphasis has to be made on the supporting pillars for the TPM program to succeed. The purpose of the study is to determine how effective the TPM program has been implemented. The successful implementation will however be determined by how thorough the TPM basics are practiced on a day to day running of plant operations. Chapter 4 analyses the relationship between TPM and the main pillars as outlined in this chapter.

It is clear that there are several factors which shape the organisations' ability to compete effectively. Thus a TPM strategy that can provide long term business sustainability is necessary. Chapter three outlines the research design and methodology followed in conducting this research.

## **Chapter 3: Research design and methodology**

### **3.1 Introduction**

This study seeks to verify whether a relationship exists between the Total Productive Maintenance program and the productivity of the organisations (see section 1.6 for objectives and hypothesis). This is a cross-sectional and an ex-post facto research design; the subjects of this research study will not be manipulated in any way.

This chapter outlines the research design and the methodology that was followed in developing the questionnaire. A discussion as to how the sampling of the subjects for this study was accomplished will be outlined. The last section of this chapter looks at how data obtained from the research instrument will be analysed to confirm the hypothesis stated in section 1.6.2.

### **3.2 The research instrument**

#### **3.2.1 Developing the research instrument**

Some considerations will have to be made in developing the questionnaire for this research study. The questionnaire was developed such that it encompasses the whole subject of the Total Productive Maintenance program. To achieve this, a detailed literature research was conducted and pre-testing (see section 3.2.2) of the research instrument was performed on the subject matter experts.

The subject matter experts include the TPM facilitators who have received high level training in Total Productive Maintenance. This has aided in revealing possible areas of improvement i.e. areas that may not have been covered by the questionnaire. Also, the need to revise some questions to ensure that all the subjects of this research can comprehend the questions with ease was identified. Over and above this, this also ensured that the instrument meets all validity criteria. A research instrument is valid if it

satisfies the content, criterion-related and construct validity (Cooper and Schindler, 2001).

Initially, the research instrument seeks to evaluate how effective the basic principles of the Total Productive Maintenance strategy are being practiced. These questions (questions 1 through question 4) assess how the respondents conceive the TPM program as well as the question of who the custodian of the program is conceived to be. The relevance of posing such questions is that it matters what the perceptions as well as the attitude towards the TPM program are. Therefore these questions all seek to ascertain whether ownership, continuous improvement and small group activities (MDT's and SBU's) initiatives have been fully integrated into the TPM program or not (see section 2.4). A multiple choice single-response scale has been applied and nominal data will be obtained thereof. Included in this is a simple category scale (question 5) for the purposes of establishing whether respondents did receive TPM specific training or not.

The second phase of the research instrument seeks to assess how effective the implementation of the TPM program is (questions 6 through question 18). The appropriate tool that has been used in this instance is the Likert scale that will yield interval data. Finally, the last section of the instrument includes unstructured questions. The rationale behind the inclusion of these questions is that respondents will get to state their views with regards to the contributions and areas of improvement in the TPM program. This will aid to a large extent in prescribing the relevant recommendations to ensure that the TPM program yields positive results.

The research instrument is used in to gather both qualitative data and quantitative data. Where necessary, unstructured interviews were conducted to obtain detailed insight into answers provided by the respondents. To counter leniency and the central tendency, some questions are rephrased in the research instrument (Cooper and Schindler, 2001). This will serve as checks and balances to ensure consistency of the answers through

reinforcing of the questions. Appendix 1 shows the research instrument that has been administered to the participants in this study.

### **3.2.2 Pretesting of the research instrument**

The research instrument has been pre-tested on a sample of 9 individuals. This sample has been obtained through nonprobability sampling. A group consisting mainly of TPM facilitators was asked to provide answers to the questions. By pre-testing the research instrument, it is possible to identify problem areas before the actual collection of data begins (Cooper and Schindler, 2001).

This also helps provide insights and ideas for refining the instrument that could otherwise result in no answers provided or incorrect responses given. Another benefit that could arise from this exercise is that the evaluation of the research instrument could also reveal whether the content covered by the questions is inclusive of the entire TPM subject.

## **3.3 Sampling design**

### **3.3.1. The sample population**

The population of interest in this research is the employees of all the companies that have implemented the Total Productive Maintenance program within the manufacturing sector in South Africa. The scope of this particular study will only cover Sappi Kraft (Ngodwana Mill) and SABMiller (Polokwane Brewery).

The frame from which the sample can be obtained is approximately 900 employees for Ngodwana Mill and approximately 180 employees for Polokwane Brewery. The employees in this research study are only permanent employees. Therefore it can be reasonably assumed that each one of these employees has had some exposure to the Total Productive Maintenance initiative. It is to be noted that individuals that perform work that

has been outsourced form part of the contractors. Therefore these individuals do not qualify to participate in this research study. The size of the sample for this research study will be greater than five percent (a total of 64 respondents) of the sample frame. This size will allow sufficient time necessary to reach all the selected respondents and time to make follow-ups whenever the need arises.

### **3.3.2 Selecting the sample**

The list of names from which the sample was drawn was obtained from the departmental heads i.e. section managers or the respective human resources managers. These departments comprise of Multidisciplinary Teams (MDT's) and the Small Business Units (SBU's), also known as Shift Based Teams (SBT's). Therefore a sufficiently representative sample was drawn.

The Multidisciplinary Team consists of all the forepersons for different sections in the factory. These include employees from the maintenance department, quality department, logistics department and production department. The management staff are also included in the Multidisciplinary Teams. On the other hand, the Small Business Units (SBU's or SBT's) are comprised of employees from specific sections or departments. Thus an SBU is made up of a specific team that looks after each department. This typically includes section artisans and all the production personnel that work in that particular section. These teams consist of various individuals who are involved at various stages of the process. Therefore both the MDT's and the SBU's or SBT's provide a good representation of each factory's population.

Stratified random sampling was used to obtain the samples from each Multidisciplinary Team and each Small Business Unit. According to Cooper and Schindler (p. 185, 2001) " the process by which the sample is constrained to include elements from each of the segments is called stratified random sampling". This probability sampling technique provides an increased statistical efficiency while at the same time providing adequate data from which statistical inferences can be made.

A disproportionate stratified sampling was performed to obtain samples from the Multidisciplinary Teams and the Small Business Units or the Shift Based Teams. The reasoning behind this is that the sizes of these teams are not exactly the same between Ngodwana Mill and Polokwane Brewery. Thus the Multidisciplinary Teams and the Small Business Units in Sappi-Ngodwana are larger in size as compared to the Multidisciplinary Teams and Small Business Units in Polokwane Brewery. As a consequence of this, a large sample was drawn from MDT's and SBU's in Ngodwana Mill. On the other hand, a smaller sample was drawn from the MDT's and SBU's in Polokwane Brewery. These samples are however still representative of the population of each respective factory. It will still be possible therefore to generalise the results obtained.

### **3.4 Data collection**

Due to the fact that this is a relatively small sample (see section 3.3.1) as compared to research studies that involve a larger population size, a single person was responsible for collecting data in the field. The respondents of this research were reached at their respective workplaces. The questionnaires were handed to them after the daily morning meetings. Prior to issuing or administering the research instrument, consent was obtained from the relevant section managers. The reasoning behind administering the instrument this way is due to the fact that both MDT and SBT members from different sections of the particular plants attend these meetings. Therefore this is the appropriate place to reach the selected respondents.

To reduce the impact of measurement errors, clearly outlined instructions accompanied the questionnaire. This was done to insure that all respondents understand how the questions were to be answered. By allowing respondents to fill out the questionnaire in the presence of the researcher, it becomes possible to address issues as they arise. In the same vein, this also allowed the researcher to seek clarity on the unstructured questions that were answered vaguely. Another benefit that arises as a consequence of the researcher being able to interact with the respondents is that callbacks are reduced drastically and this also saves coding time.

All the questionnaires obtained from the respondents were checked for completeness upon returning by the respondents. Where necessary, elaboration was sought to ascertain accuracy of data. A few cases were encountered whereby the selected respondents were not available at the time of administering the research instrument. This was mostly due to individuals either being on afternoon shift, night shift or due to the individual being off-shift at the time when the research instrument was administered.

The factories under consideration run on a continuous basis and hence the shift system, with the exception of Polokwane Brewery. This factory runs continuously only during the course of the week. To get around the problem of unavailable respondents, some callbacks had to be made. This was after ascertaining with the relevant section managers or supervisors the time that the respondents would become available. As a result, all the selected respondents managed to return the completed questionnaires. The time taken to complete the data collection phase is approximately three.

### **3.5 Analysis of data**

Due to different combination of questions' type in the research instrument, it will become necessary to employ various methods to evaluate data. The following subsections look at how data will be presented for analysis purposes in chapter 4.

#### **3.5.1 Presenting the TPM principles results**

To analyse this data (questions 1 through question 4), data will be entered into the SPSS software. The information that will be obtained from this data will classify the answers into five separate classes (categorical). It will be possible to obtain frequency tables, which basically provide a summary of all the responses. The mapping of the individual questions from the questionnaire will be 1 to 5 for responses or selections A to E from the questionnaire. This will be done through the SPSS software. Frequency tables

will be used to compile bar charts for the results. From the bar charts, the percentage of each category will be shown. This will aid in establishing what the opinions of the respondents are with regards to the Total Productive Maintenance principles. Presentation of data in a bar chart format is especially applicable when the variables under consideration are nominal (Schindler and Cooper, 2001). Therefore the use of bar charts is justifiable and relevant in this instance.

### **3.5.2 TPM training data presentation**

This rating scale (simple category scale, question 5) provides nominal data where two mutually exclusive response choices are sought. A bar chart will also be used to assess the level of TPM training of the employees of the two factories.

### **3.5.3 TPM effectiveness data presentation**

As mentioned above, the use of the Likert rating scale (questions 6 through question 18) yields interval data. This data is suitable for producing descriptive statistical information from which inferences regarding the effectiveness of the TPM program will be made. The mapping of the individual questions will be 1 to 5 for responses or selections A to E from the questionnaire. This will also be done through the SPSS software. This will assist in compiling and analysing statistical data for the survey. From the information that will be obtained, it will be confirmed using the t-test method whether or not a relationship exists between the Total Productive Maintenance program and variables such as costs, productivity and employee safety.

For the purposes of this research, a 95% degree of confidence will be placed on the results of the survey. This effectively means that the corresponding level of significance is 0.05. The reasoning behind choosing such level of significance is due to the fact that accuracy is not of the utmost importance in this instance. Where precision is necessary due to risk involved in making statistical inferences, it would be necessary to have a higher level of

significance (Schindler and Cooper, 2001). Parametric tests will be used to test the level of significance as this is interval data.

#### **3.5.4 Coding and presenting TPM contributions and improvement areas**

To analyse and interpret the open-ended questions (questions 19 and 20), the content analysis technique will be used. This technique will be instrumental in aiding with the analysis of the unstructured questions and prescribing of the necessary recommendations.

### **3.6 Conclusions**

The use of different scales in the research instrument will provide this research study with ample information from which the analysis can be made. This is also augmented by the unstructured questions posed in the research instrument. The analysis will present challenges with regards to the fact that all the information collected will have to be consolidated. This needs to be done such that a single conclusion concerning the effectiveness of the Total Productive Maintenance initiative can be drawn. The results of data obtained from the survey are presented in the next chapter.

## **Chapter 4: Results of the survey**

### **4.1 Introduction**

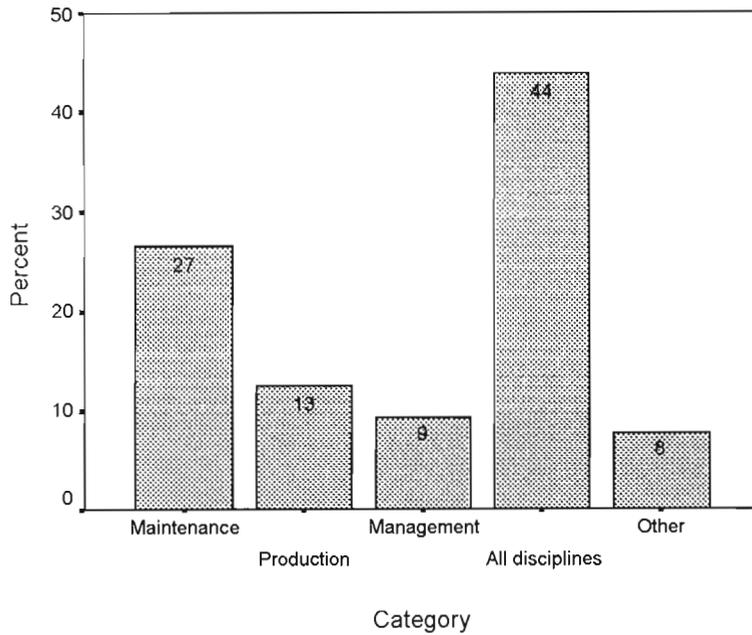
The findings of the research study are presented in this chapter. These results are presented in the same chronological order as they appear in the questionnaire (see appendix 1). First the responses concerning TPM principles and TPM training are presented. These include questions 1 through question 5 in the research instrument. The second section of this chapter presents data obtained from the TPM effectiveness questions i.e. questions 6 through question 18. In the last section of this chapter, responses to the open-ended questions are presented.

### **4.2 Respondents opinions on TPM Principles**

**Question 1. Disciplines involved with TPM.** From figure 4.1, most participants (44%) indicated that all disciplines were involved with the TPM program. There is also a significant number, i.e. 27% of the respondents that felt that maintenance discipline is mostly involved with the TPM program in their factories.

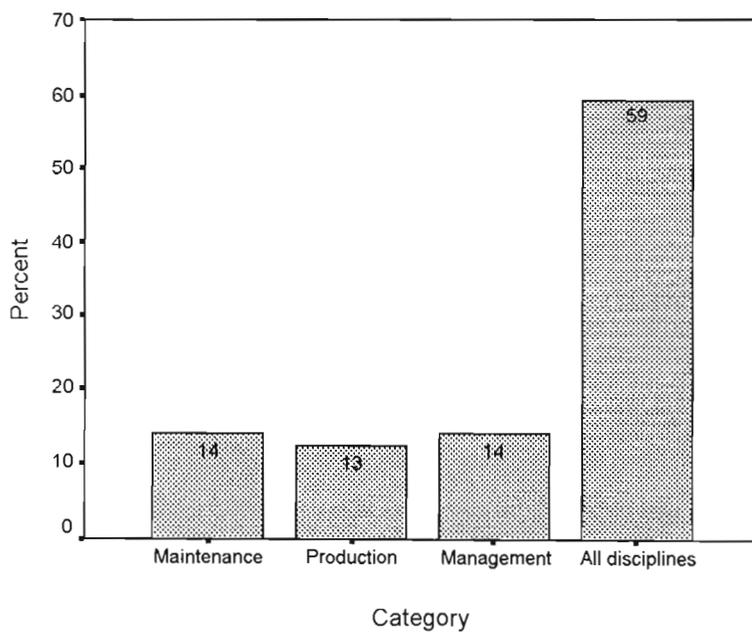
While 13% felt that the production department is mostly involved with TPM, the balance of the scores are shared almost evenly between management and the others category. The others category includes a combination of quality department, training department and in some cases, some respondents felt none of the departments is really involved with TPM.

**Figure 4.1 TPM involvement**



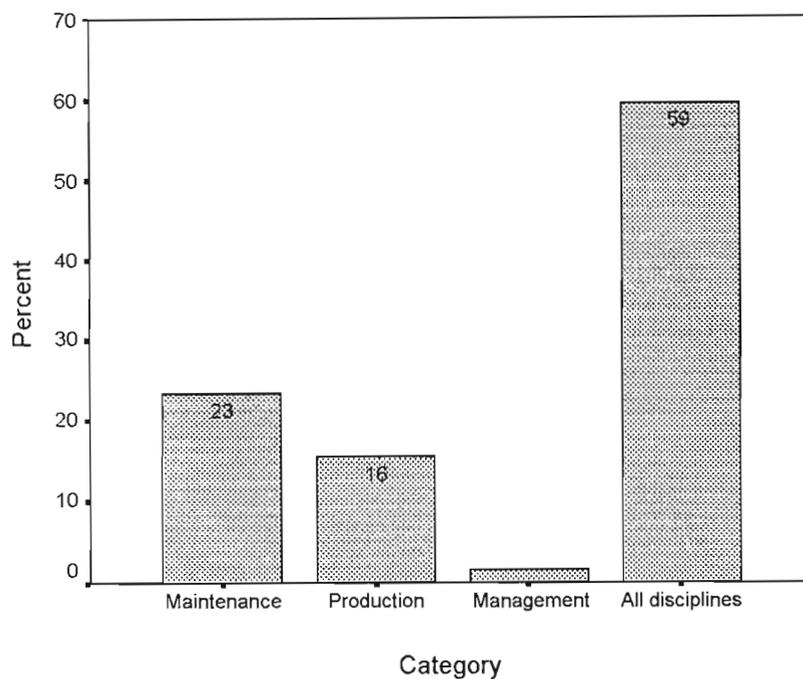
**Question 2. Improvement suggestions.** Figure 4.2 shows that it is widely perceived (by about 59% of the respondents) that all disciplines contribute towards initiating improvement suggestions. However, a total of 41% of the polled respondents feel that improvement suggestions are initiated almost evenly between the maintenance, production and management disciplines.

**Figure 4.2 Improvement suggestions**



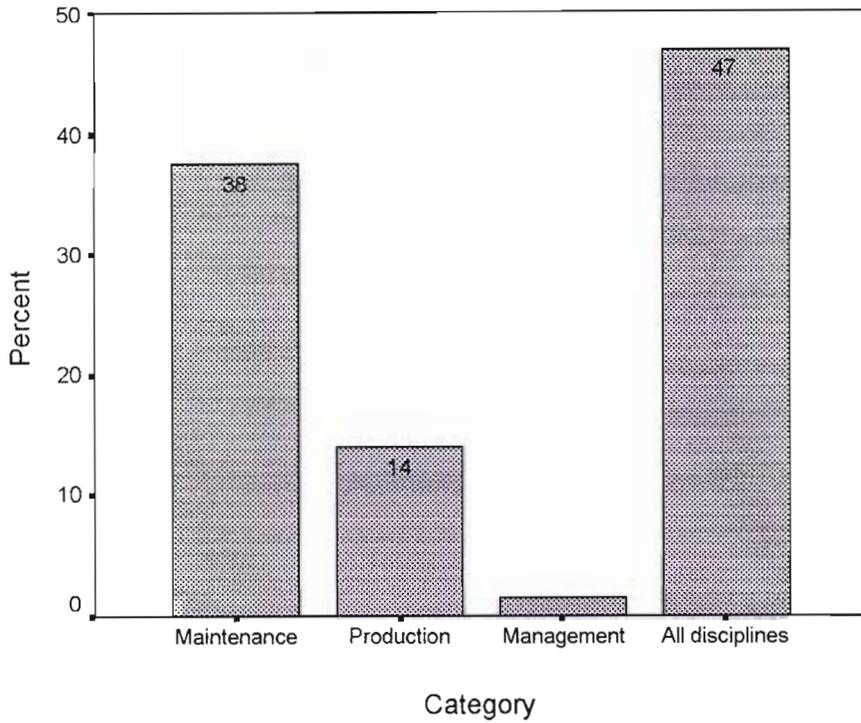
**Question 3. Problem solving.** About 59% of respondents gave the indication that all disciplines are involved with problem solving in their workplace as indicated in figure 4.3. This is a fairly high percentage considering that it is followed by 23% of respondents who indicated that the production department gets involved with problem solving. Only about 2% of respondents felt that management gets involved in problem solving.

**Figure 4.3 Problem solving involvement**



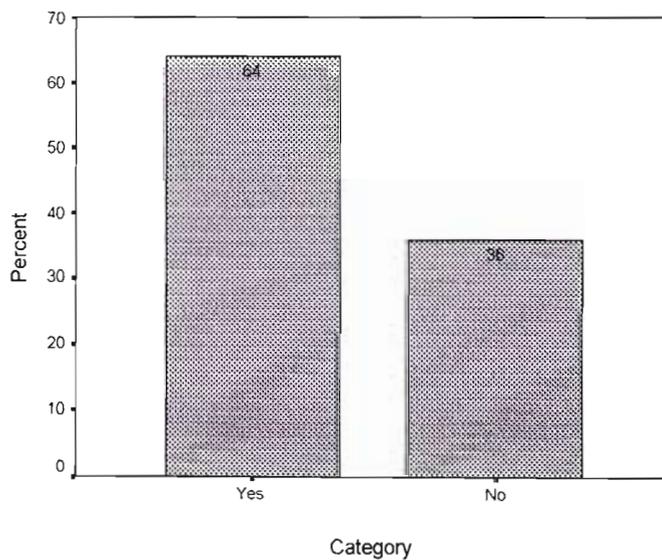
**Question 4. Equipment downtime responsibility.** As can be seen if figure 4.4, responses to this question show a similar trend to figure 4.3 above. However, about 47% of the respondents indicated that all disciplines were responsible for equipment downtime as compared to 38% who felt that the maintenance department is responsible for equipment downtime. Only 2% of respondents indicated that management is responsible for equipment downtime.

**Figure 4.4 Equipment failure/stoppage responsibility**



**Question 5: Received TPM training or not.** Figure 4.5 shows that a large number of respondents indicated that they have been formally trained on TPM. There is still a significant number (36%) of the employees who have never received any formal training in the Total Productive Maintenance program.

**Figure 4.5 Employee TPM training**



These results of questions 1 through question 5 will be assessed in comparison to results of questions 6 through question 18. These (questions 6 through question 18) contain the independent variables of the hypothesis. This comparison should give an indication as to whether the Total Productive Maintenance principles are well entrenched. Further, it will be ascertained whether the TPM initiative does impact positively on the productivity of the organisations, amongst other variables.

### **4.3 TPM effectiveness results**

In this section, statistical tests are performed to confirm the hypothesis for this research study. Frequency tables are used to compile a table of responses (in percentages) in order to verify the results obtained from the statistical tests.

#### **4.3.1 Statistical results from the survey**

This subsection outlines the results for questions 6 through question 18. Using a level of significance of 0.05, the results illustrated in table 4.1 were obtained using the t-test method.

In the absence of industry population mean, a population mean of 2.50 is assumed for the purposes of performing the statistical tests. This is merely the median of the data used in this research on the scale of 1 to 5. This will form the basis for the null hypothesis. The critical value obtained is 1.67 (see appendix 5) and will be used for all the questions. Appendix 5 shows calculations for question 6, the other questions were calculated in a similar way.

**Table 4.1 Statistical tests results**

Question Number	Aspect	Mean Statistic	Standard Error	Calculated Value	Interpretation
Q6	Productivity	2.20	0.124	-2.40	Accept
Q7	Equipment downtime	2.13	0.119	-3.15	Accept
Q8	Process downtime	2.16	0.130	-2.65	Accept
Q9	Runrate	2.61	0.125	0.87	Accept
Q10	Quality	2.13	0.110	-3.41	Accept
Q11	Availability	2.55	0.118	0.40	Accept
Q12	Costs	2.64	0.127	1.11	Accept
Q13	Safety	2.25	0.141	-1.77	Accept
<b>Q14</b>	<b>Motivation</b>	<b>3.08</b>	<b>0.141</b>	<b>4.10</b>	<b>Reject</b>
<b>Q15</b>	<b>Visual system</b>	<b>3.08</b>	<b>0.148</b>	<b>3.91</b>	<b>Reject</b>
Q16	Housekeeping	2.39	0.140	-0.78	Accept
Q17	Operability	2.47	0.134	-0.23	Accept
Q18	Maintainability	2.55	0.137	0.34	Accept

From the table above, it appears that TPM does impact positively on the productivity of organisations. The same can be said about plant availability and downtime. The t-test also reveals that TPM impacts positively on quality, speed, cost and safety of employees. However, respondents feel that TPM does not influence employee morale and the use of visual systems. On the other hand, it can be observed that TPM does improve machine operability and maintainability. Appendix 4 shows statistical data for the survey.

#### **4.3.2 Percentage representation for TPM effectiveness**

Using frequency distributions for questions 6 through question 18, table 4.2 was constructed. Cumulative frequencies for *Strongly Agree* and *Agree* options are shown in the third column. The *Neither Agree nor Disagree* option has been taken as is from the frequency tables and this is indicated in the fourth column. The cumulative percentages for *Disagree* and *Strongly Disagree* options are shown in the fifth column. To see the frequency tables for each question, see appendix 6.

**Table 4.2 TPM effectiveness**

Question Number	Aspect	Strongly Agree &/or Agree	Neither Agree nor Disagree	Disagree &/or Strongly Disagree	Total Percentage
Q6	Productivity	70.3%	14.1%	15.6%	100%
Q7	Equipment downtime	73.4%	14.1%	12.5%	100%
Q8	Process downtime	76.6%	10.9%	12.5%	100%
Q9	Runrate	50.0%	28.1%	21.9%	100%
Q10	Quality	70.3%	21.9%	7.8%	100%
Q11	Availability	56.3%	25.0%	18.7%	100%
Q12	Costs	45.3%	32.8%	21.9%	100%
Q13	Safety	64.1%	21.9%	14.0%	100%
<b>Q14</b>	<b>Motivation</b>	<b>40.6%</b>	<b>15.6%</b>	<b>43.8%</b>	<b>100%</b>
<b>Q15</b>	<b>Visual system</b>	<b>37.5%</b>	<b>21.9%</b>	<b>40.6%</b>	<b>100%</b>
Q16	Housekeeping	64.1%	14.1%	21.8%	100%
Q17	Operability	54.7%	25.0%	20.3%	100%
Q18	Maintainability	54.7%	21.9%	23.4%	100%

By comparing columns three, four and five in table 4.2, the majority of the respondents agree that TPM impacts positively on all the relevant aspects except for Employee morale and Visual systems. For instance, 64% of the respondents feel that TPM improves cleanliness (housekeeping) of the workplace. However, 22% of the respondents feel that TPM does not improve the cleanliness of the workplace. In the same vein, only 14% of the sampled population indicated their neutral stance with regards to TPM improving workplace cleanliness. About 41% of the respondents indicated that they agreed that TPM has led to higher employee morale. However, 44% of the respondents disagreed that TPM has led to higher employee morale. It can be said therefore that these results fully agree with the results illustrated in table 4.1.

An interesting observation is that aspects with the lowest mean scores have the highest percentage of responses indicating that TPM impacts positively on some of the independent variables (see tables 4.1 and 4.2). The equipment downtime and quality aspects both have a mean score of 2.13. Both these

aspects show 73% and 70% of the respondents respectively indicating that TPM has had a positive impact on the downtime and quality aspects. The mean of the cost aspect is 2.64, with the calculated value of 1.11 that is marginally close to the critical value of 1.67. This shows that the hypothesis that without implementing TPM, organisations can not reduce their costs is close to rejection. This is also confirmed by the fact that only 45% of the respondents indicated that TPM has led to reduction in costs in table 4.2. This compares to 22% of the respondents indicating otherwise and 33% neutral responses. Appendix 7 illustrates a comparison of the mean values.

#### 4.4 The effect of TPM training on respondents' perceptions

In this section, cross-tabulated results of TPM specific training is analysed against certain TPM principles as perceived by the respondents. This will help ascertain whether TPM training has been effective or not. Where training has not been given, it will reveal if there is necessity for TPM specific training.

Table 4.3 illustrates the number of employees who have been trained in TPM and those that have not been trained. This is in comparison to the responses given to the TPM involvement question (question 1). About 19 (30%) respondents that have received TPM training indicated that all disciplines are largely involved with TPM. About 14 (22%) respondents that have received TPM training indicated that maintenance is involved with TPM.

**Table 4.3 Received training and TPM involvement**

		Discipline					
		Maintenance	Production	Management	All disciplines	Other	Total
Received Training	Yes	14	4	3	19	1	41
	No	3	4	3	9	4	23
Total		17	8	6	28	5	64

Of the 41 respondents that have been trained in TPM in table 4.4, 16 (25%) respondents indicated that downtime is the responsibility of maintenance department. In the same category, 22 (34%) respondents showed that downtime is the responsibility of all disciplines. On the other hand, 8 (13%) respondents that have not been trained on TPM indicated that equipment downtime is equally a maintenance department's responsibility as is all disciplines' responsibility.

**Table 4.4 Received training and Downtime responsibility**

		Discipline					
		Maintenance	Production	Management	All disciplines	Other	Total
Received	Yes	16	3	0	22	0	41
Training	No	8	6	1	8	0	23
Total		24	9	1	30	0	64

From table 4.5, a total number of 30 (47%) employees that have been trained in TPM agree that TPM has resulted in improved productivity. This includes both the *Strongly Agree* and *Agree* categories. Only 6 (9%) trained participants disagreed. However, of the 23 respondents that have not been trained in TPM, 15 (23%) respondents indicated that TPM has had positive influence on reduced quality defects.

**Table 4.5 Received training and Improved production output**

		Agree Strongly	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total
Received	Yes	11	19	5	6	0	41
Training	No	5	10	4	4	0	23
Total		16	29	9	10	0	64

A similar trend as the one in table 4.5 can be observed in table 4.6. A total of 31 (48%) trained respondents feel that TPM has led to reduced quality defects. On the other hand, a total of 14 (22%) respondents without TPM training feel that quality defects have decreased since TPM was introduced.

**Table 4.6 Received training and Less quality defects**

	Agree Strongly	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total
Received Training Yes	10	21	6	4	0	41
Received Training No	6	8	8	1	0	23
Total	16	29	14	5		64

As can be seen from table 4.7, the majority of employees feel that TPM has resulted in reduced safety incidents. This includes both the categories of employees who have been trained in TPM and those that have not been trained in TPM. About 14 (22%) respondents are neutral in this regard.

A total of 5 (8%) respondents without TPM training indicated that TPM has not influenced employee safety. On the other hand, only 4(6%) employees that are without TPM training indicated that TPM has not influence employee safety. This includes both the *Disagree* and *Strongly Disagree* categories.

**Table 4.7 Received training and Reduced safety incidents**

	Agree Strongly	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total
Received Training Yes	7	18	11	4	1	41
Received Training No	12	4	3	2	2	23
Total	19	22	14	6	3	64

## **4.5 TPM contributions and improvement areas**

This section summarises the views of the research participants with regards to the Total Productive Maintenance program. Only the constructive comments regarding the TPM program will be summarised and used to formulate some recommendations.

### **4.5.1 Describe how TPM has contributed positively in your plant?**

The following is a summary of the responses to the above question by the selected employees.

- Total Productive Maintenance has brought about some improvement in both the operating and maintenance practices.
- TPM has improved the quality of work life and as a result, machine efficiencies have improved.
- TPM has created awareness and better understanding of business requirements and processes.
- A considerable number of bottlenecks (problem areas) have been reduced as a result of the Total Productive Maintenance program.
- Improved housekeeping as a result of TPM has created safer working environment.
- TPM highlights problem areas and corrective actions are taken to rectify these.
- TPM shares responsibility across all disciplines and therefore it becomes simpler to address problem areas.
- Throughout all disciplines, TPM has enabled employees in the shop floor to realise how they impact on business profitability and sustainability.
- There has been improved machine uptime and reduced equipment failure rate as a result of TPM.

- TPM has removed all of the traditional barriers between the maintenance departments, the production departments and other disciplines. This has eliminated the shifting of blame amongst disciplines.
- TPM has provided a more structured failure cause analysis approach to identify root causes of problems.

#### **4.5.2 In what respect is TPM not addressing concerns in your plant/department?**

The following responses were given from the selected employees when asked the question above.

- TPM is not aiding in changing the attitudes of employees who are supposed to make the program work.
- TPM has not shown any improvement in work commitment, hence there are a lot of areas that still need improving.
- TPM is not fully implemented across all disciplines and hence the full potential of the TPM program has not been realised.
- TPM has not caused any changes in the workplace due to lack of interest in TPM from the workforce.
- TPM does not recognise the role of the original equipment manufacturers in identifying and solving problems.
- TPM is not effective as a result of very little awareness amongst employees.
- TPM does not recognise employee efforts.

#### **4.6 Discussion and analysis of the survey**

The survey has revealed that basic Total Productive Maintenance principles are not well understood. Over and above this, some of these principles are not well entrenched by the organisations that have implemented the TPM program. The fact that some respondents felt that either maintenance or production departments are involved with TPM or the initiation of improvement suggestions supports this argument. Another observation that can be made from the results is that employees are not certain as to who the custodian of Total Productive Maintenance program is.

The statistical results have shown a remarkable positive relationship between the Total Productive Maintenance program and various aspects that were measured. The results revealed that organisations that have implemented TPM have had an increase in their production output. This compares closely with reduced downtime, better quality products, increased machine speed and lower production/maintenance costs. The results indicate that it has also become easier to operate and work on plant equipment. The tabulated results from frequency distributions also showed that TPM has led to increased productivity reduced costs and a safer working environment. This implies that there is consistency in the responses provided and the results obtained.

No significant differences were found in responses from employees that have received TPM training and those that have not been trained. However, a large portion of all the respondents from both categories (trained and not trained) are still not clear on some of the TPM principles. This can be explained by the fact that TPM training was carried out on a once-off basis when the program was introduced. The results of TPM's contributions reveal that the program has had positive spin-offs for organisations that have implemented the program. However, there are also some negative sentiments that are evident with regards to TPM influencing productivity. These can be attributed to lack of proper implementation of the Total Productive Maintenance program.

## **Chapter 5: Conclusions and recommendations**

### **5.1 Conclusions**

Based on the analysis of the survey, the following conclusions have been drawn:

- The involvement of employees with the TPM program and the initiation of improvement suggestions are largely seen to include all disciplines. Also, problem solving and equipment downtimes are seen to include all disciplines. However, some employees feel that specific disciplines are responsible for making improvement suggestions, addressing problems and resolving downtime. From this, it can be concluded that some employees are not well informed on the principles of TPM and how TPM can support business objectives. Training on the Total Productive Maintenance principles is lacking.
- Statistical results confirm that the TPM program impacts positively on productivity, downtime, quality and availability of the organisations. The table showing employee responses (in percentages) with regards to the TPM effectiveness has confirmed these results. Therefore the hypothesis that without implementing TPM, organisations can not achieve increased productivity and meet their quality targets is true. Results also show that Total Productive Maintenance reduces employees' exposure to safety hazards.
- There has been an increase in the availability (reduced downtime) of machines, run rates and improved quality as a result of the Total Productive Maintenance program. It can be concluded that the Overall Equipment Effectiveness of the organisations has increased as result of the Total Productive Maintenance program. Therefore reduced downtime and increased availability of plant equipment has led to increased plant efficiency.

- Statistical results show that visual systems and employee morale have not improved since the Total Productive Maintenance program was introduced. Frequency figures (in percentages) for employee responses also confirmed this. This can be attributed partly to the fact that the TPM program has not been fully implemented in these organisations. Secondly, the lack of motivation in the workforce can be attributed to employees' achievements not being recognised. This finding emerged from the employees' concerns with regards to the TPM program. This has resulted in lack of ownership on the part of employees with regards to the workplace or process.
- Finally, the results show that the Total Productive Maintenance program has made it easier to operate and maintain plant equipment. Therefore improvement suggestions that have come from the small group activities have improved the ease of operation and maintenance of plant equipment.

## 5.2 Recommendations

The recommendations made here should serve as the new strategy to ensure that the Total Productive Maintenance program improves the competitiveness of organisations. The following recommendations are made on the basis of the survey results:

- TPM specific training should be conducted to clarify the role of the Total Productive Maintenance program. Initially, this should include all employees. New employees that join the organisations should also be taken through the Total Productive Maintenance training as part of induction. It is also necessary to re-visit TPM training on a regular basis to ensure that all TPM principles are well understood and the focus is sustained. It is the duty of the TPM facilitators and management to identify such needs as they interact with the employees.

Plant personnel need to be trained in problem solving skills using a formal methodology. By using a common approach, everyone will bring a common perspective to assessing performance problems and developing recommendations. After this training, groups will need the support of TPM facilitators who have received specialised training in TPM. Plant operators need to be trained to perform autonomous maintenance. This will allow more time for maintenance personnel to concentrate on performing proactive maintenance (maintenance schedules) as opposed to breakdown (reactive) maintenance.

- The use of visual systems needs improving. Work instructions and procedures should be developed and used by all disciplines. To develop these, the first step is to determine the critical information needed to make the equipment easier to operate, maintain and inspect. Secondly, the correct information and reliable application methods should be determined. These should be used to communicate specific information at the point of

use or near the equipment. Proper use of visual systems facilitates problem solving and management of objectives.

- Employee contributions and achievements need to be recognised and applauded. This will help motivate employees to a large extent and ensure changes in attitudes.
- To improve ownership of processes, management needs to empower all the employees to make decisions affecting their work environment. This implies that all employees need to be actively involved in the decision making process. This will also drive the necessary changes in attitude, motivate employees and establish a culture of teamwork.
- The maintenance, production and quality departments need to restructure such that all personnel fall under one department. By restructuring these departments, everyone will become actively involved in driving the TPM program and achievement of performance objectives. This will eliminate the barriers that exist amongst all these departments. Therefore all employees will share the same responsibility without necessarily shifting blame amongst each other.
- The implementation process of the Total Productive Maintenance program should be performed in phases. The following phases are recommended (Keneddy, 2002):
  - (i) Awareness phase: This phase involves TPM education and training as outlined above. This includes developing of the Total Productive Maintenance introduction strategy.
  - (ii) Learning phase: This involves the introduction of the TPM to two or more pilot areas. This should incorporate the focussed equipment, process improvement, work area management and operator equipment management pillars (see section 2.5).

- (iii) Assessment phase: This involves development of a site-wide implementation plan based on the learning phase above.
- (iv) Site-wide implementation phase: This involves the cascade of TPM throughout the entire site.

By systematically implementing TPM, firms will ensure that all efforts are sustained. These steps are also recommended for organisations wishing to implement TPM for the first time.

- The progress on the implementation of the Total Productive Maintenance program needs to be reviewed on a regular basis. It is proposed that a TPM steering committee be formed. This committee should comprise of TPM facilitators, production managers and maintenance managers. The committee's duty should include reviewing the progress on TPM initiatives, looking at ways to promote TPM throughout the plant and ensuring that TPM efforts are sustained.

Organisations need to measure their current performances and use these as benchmarks. Through monitoring performance, areas of improvement will be identified. Therefore the use of the Overall Equipment Effectiveness should become fully entrenched. This should also be used as an audit tool to evaluate the progress of TPM implementation.

By implementing these recommendations, all the organisations that have implemented the Total Productive Maintenance program will achieve their drive towards enhanced world class competitiveness. This will be achieved through continuous learning and participation of all employees. Consequently, organisations will be able to provide quality products, faster and more cost effectively than competitors. However, it should be acknowledged that TPM is not a short-term fix but a journey. The time frame for full implementation

varies, depending upon where a company is in relation to its maintenance, production and quality activities.

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# APPENDICES

## APPENDIX 1 : TPM Opinion Survey Questionnaire

Please place a cross (x) next to the most appropriate answer.

1. Which one of the following disciplines is mostly involved with TPM in your plant / department?
  - A. Maintenance (Engineering)
  - B. Production
  - C. Management
  - D. All disciplines
  - E. Other (Specify: \_\_\_\_\_)
  
2. Who is responsible for initiating improvement suggestions in your work area / department?
  - A. Maintenance (Engineering)
  - B. Production
  - C. Management
  - D. All disciplines
  - E. Other (Specify: \_\_\_\_\_)
  
3. Who gets involved with problem solving in your plant (e.g. Formal failure analysis or 5 Why)?
  - A. Maintenance (Engineering)
  - B. Production
  - C. Management
  - D. All disciplines
  - E. Other (Specify: \_\_\_\_\_)
  
4. Plant stoppages / Equipment failures is a responsibility of the following?
  - A. Maintenance (Engineering)
  - B. Production
  - C. Management
  - D. All disciplines
  - E. Other (Specify: \_\_\_\_\_)
  
5. Have you received any training on TPM?      Yes                      /                      No

Please indicate your degree of agreement with the statements below, please check (x) your answer as follows:

Strongly Agree	Agree	Neither agree Nor disagree	Disagree	Strongly Disagree
A	B	C	D	E

TPM has shown / is showing **improvement** on the following?

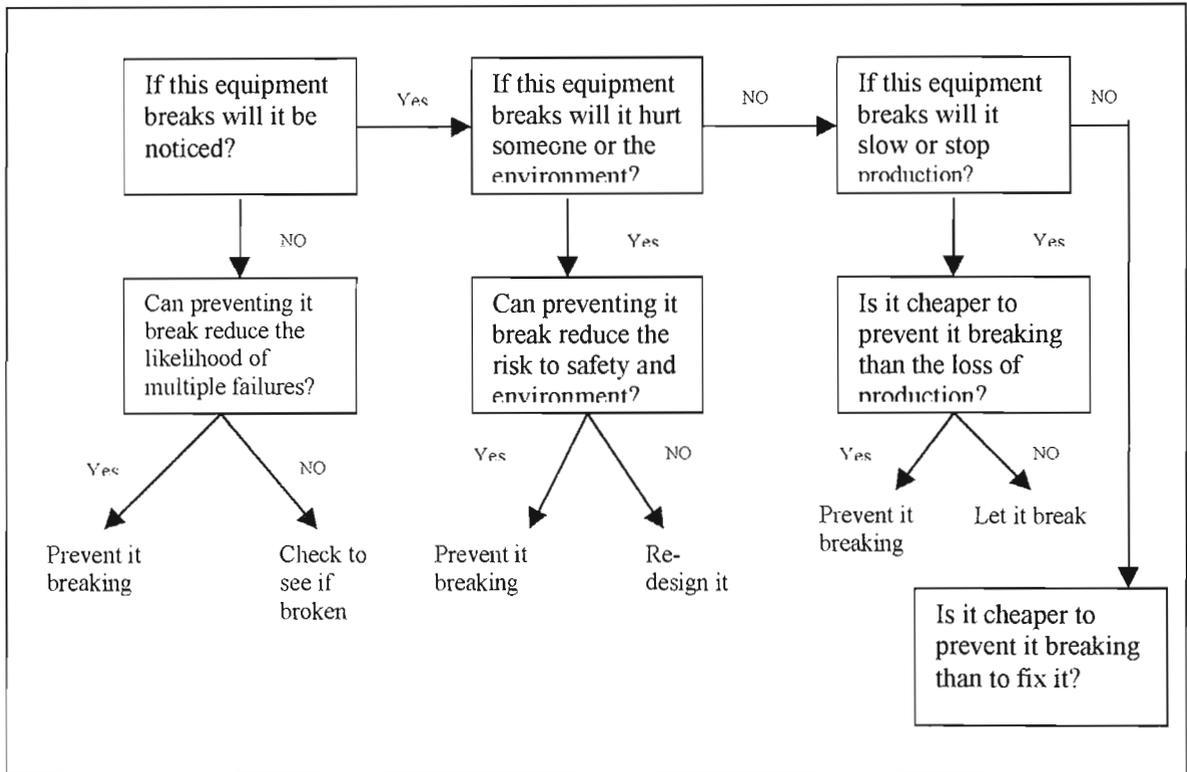
- |  |           |
|--|-----------|
| 6. Production (e.g. more tonnage/day produced or litres/day produced). | A B C D E |
| 7. Equipment related downtime (less equipment downtime).               | A B C D E |
| 8. Production related downtime (less process interruptions)            | A B C D E |
| 9. The machine run rate / speed (e.g. meters/min)                      | A B C D E |
| 10. Product quality (less quality defects).                            | A B C D E |
| 11. Machine availability has improved considerably.                    | A B C D E |
| 12. Maintenance/Production costs (reduced cost).                       | A B C D E |
| 13. Safe working environment (reduced safety incidents).               | A B C D E |

- 14. Motivation to perform duties. A B C D E
- 15. The use of visual systems (e.g. demarcation, marking of pressure gauges) A B C D E
- 16. Cleanliness of the work area. A B C D E
- 17. It is easier to operate plant equipment/machinery. A B C D E
- 18. It is easier to work on plant equipment/machinery. A B C D E

19. Describe how TPM has contributed positively in your plant?.....  
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20. In what respect is TPM not addressing concerns in your plant/department?.....  
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**APPENDIX 2: Sample RCM Logic Diagram**



Source: Sappi Management Services, 2001, *Maintenance Management Handbook*, p.70.

## **APPENDIX 3 : Sappi's TPM Objectives and Principles**

### SAPPI TPM OBJECTIVES

- 1) To maximise equipment effectiveness and productivity by eliminating all machine losses.
- 2) To create a sense of "ownership" on the part of business unit team through a programme of training and involvement.
- 3) To promote continuous improvement through small group activities involving production, quality and maintenance personnel.

### SAPPI TPM Principles

- 1) Practise a philosophy of continuously making small improvements placing greater emphasis on the cumulative effect of small improvements than the search for a single large improvement.
- 2) Practise a philosophy of continuously eliminating waste i.e. anything that does not add value to the finished product.
- 3) Practice a philosophy of respecting employees for their knowledge and ability to make a contribution to the improvement process.
- 4) Practise a philosophy of improving the value adding process to improve both product quality and productivity.

Source: Sappi Management Services, 2001, *Maintenance Management Handbook*, p.3.

#### APPENDIX 4: Statistical data for the survey

Question	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Error	Std. Deviation Statistic
Improved production output	64	1.0	4.0	2.203	0.124	0.994
Less equipment downtime	64	1.0	4.0	2.125	0.119	0.951
Less process downtime	64	1.0	5.0	2.156	0.130	1.042
Increased run rates	64	1.0	5.0	2.609	0.125	1.002
Less quality defects	64	1.0	4.0	2.125	0.110	0.882
Improved machine availability	64	1.0	5.0	2.547	0.118	0.941
Reduced overall costs	64	1.0	5.0	2.641	0.127	1.013
Reduced safety incidents	64	1.0	5.0	2.250	0.141	1.126
Better visual systems	64	1.0	5.0	3.078	0.141	1.131
Improved employee morale	64	1.0	5.0	3.078	0.148	1.186
Improved housekeeping	64	1.0	5.0	2.391	0.140	1.121
Improved operability	64	1.0	5.0	2.469	0.134	1.068
Improved maintainability	64	1.0	5.0	2.547	0.137	1.097
Valid N (Listwise)	64					

## APPENDIX 5: Significance test for Question 6

1. Null Hypothesis:  $H_0 = 2.5$  (Without implementing TPM, organisations can not achieve increased productivity)

Alternative Hypothesis:  $H_A > 2.6$  (Without implementing TPM, organisations can achieve increased productivity)

2. Statistical test: Use t-test as data are interval measurements

3. Significance level:  $\alpha = 0.05$ , with  $n = 64$  (sample size)

4. Calculate t-value:

$$t = (\text{mean value} - \text{population mean}) / \text{standard error}$$

$$= (2.20 - 2.50) / (0.124)$$

$$= -2.42$$

5. Critical test value:

$$\text{Degrees of freedom} = n - 1 = 64 - 1 = 63$$

$$\text{Level of significance: } \alpha = 0.05$$

Therefore Critical Value = 1.67 (Obtained from the Critical Values table of t, for given probability levels)

6. Interpretation: In this instance (question 6), the calculated value is less than the critical value ( $-2.42 < 1.67$ ), therefore we **accept** the null hypothesis that without TPM, organisations can not have increased productivity.

*The same procedure has been followed for questions 7 through question 18.*

**APPENDIX 6: Percentage/frequencies for question 6 through question 18**

Question 6: Improved production output

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	16	25.0	25.0	25.0
	Agree	29	45.3	45.3	70.3
	Neither Agree nor Disagree	9	14.1	14.1	84.4
	Disagree	10	15.6	15.6	100.0
	Strongly Disagree	0	0	0	100.0
	Total	64	100.0	100.0	

Question 7: Less equipment downtime

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	17	26.6	26.6	26.6
	Agree	30	46.9	46.9	73.4
	Neither Agree nor Disagree	9	14.1	14.1	87.5
	Disagree	8	12.5	12.5	100.0
	Strongly Disagree	0	0	0	100.0
	Total	64	100.0	100.0	

Question 8: Less process/production downtime

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	16	25.0	25.0	25.0
	Agree	33	51.6	51.6	76.6
	Neither Agree nor Disagree	7	10.9	10.9	87.5
	Disagree	5	7.8	7.8	95.3
	Strongly Disagree	3	4.7	4.7	100.0
	Total	64	100.0	100.0	

## Appendix 6 (continued)

### Question 9: Increased run rates

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	8	12.5	12.5	12.5
	Agree	24	37.5	37.5	50.0
	Neither Agree nor Disagree	18	28.1	28.1	78.1
	Disagree	13	20.3	20.3	98.4
	Strongly Disagree	1	1.6	1.6	100.0
	Total	64	100.0	100.0	

### Question 10: Less quality defects

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	16	25.0	25.0	25.0
	Agree	29	45.3	45.3	70.3
	Neither Agree nor Disagree	14	21.9	21.9	92.2
	Disagree	5	7.8	7.8	100.0
	Strongly Disagree	0	0	0	100.0
	Total	64	100.0	100.0	

### Question 11: Improved machine availability

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	6	9.4	9.4	9.4
	Agree	30	46.9	46.9	56.3
	Neither Agree nor Disagree	16	25.0	25.0	81.3
	Disagree	11	17.2	17.2	98.4
	Strongly Disagree	1	1.6	1.6	100.0
	Total	64	100.0	100.0	

## Appendix 6 (continued)

### Question 12: Reduced overall costs

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	9	14.1	14.1	14.1
	Agree	20	31.3	31.3	45.3
	Neither Agree nor Disagree	21	32.8	32.8	78.1
	Disagree	13	20.3	20.3	98.4
	Strongly Disagree	1	1.6	1.6	100.0
	Total	64	100.0	100.0	

### Question 13: Reduced safety incidents

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	19	29.7	29.7	29.7
	Agree	22	34.4	34.4	64.1
	Neither Agree nor Disagree	14	21.9	21.9	85.9
	Disagree	6	9.4	9.4	95.3
	Strongly Disagree	3	4.7	4.7	100.0
	Total	64	100.0	100.0	

### Question 14: Improved employee morale

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	3	4.7	4.7	4.7
	Agree	23	35.9	35.9	40.6
	Neither Agree nor Disagree	10	15.6	15.6	56.3
	Disagree	22	34.4	34.4	90.6
	Strongly Disagree	6	9.4	9.4	100.0
	Total	64	100.0	100.0	

## Appendix 6 (continued)

### Question 15: Better visual systems

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	5	7.8	7.8	7.8
	Agree	19	29.7	29.7	37.5
	Neither Agree nor Disagree	14	21.9	21.9	59.4
	Disagree	18	28.1	28.1	87.5
	Strongly Disagree	8	12.5	12.5	100.0
	Total	64	100.0	100.0	

### Question 16: Improved housekeeping

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	14	21.9	21.9	21.9
	Agree	27	42.2	42.2	64.1
	Neither Agree nor Disagree	9	14.1	14.1	78.1
	Disagree	12	18.8	18.8	96.9
	Strongly Disagree	2	3.1	3.1	100.0
	Total	64	100.0	100.0	

### Question 17: Improved equipment operability

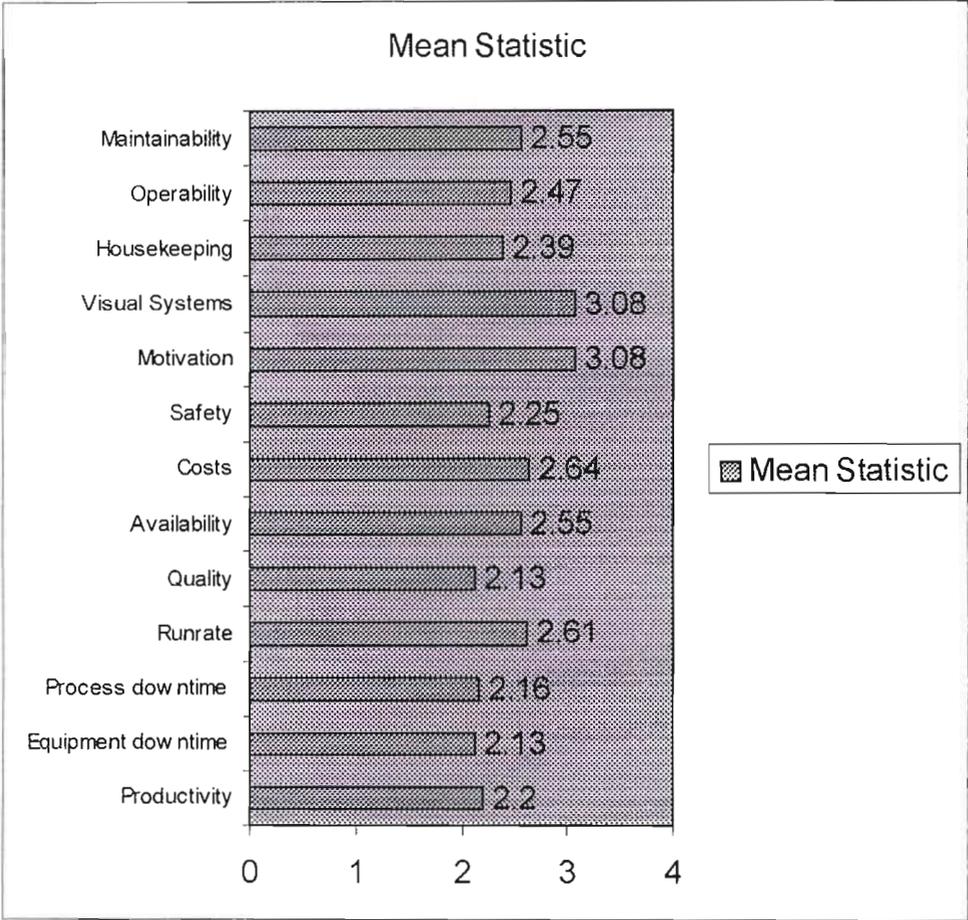
		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	13	20.3	20.3	20.3
	Agree	22	34.4	34.4	54.7
	Neither Agree nor Disagree	16	25.0	25.9	79.7
	Disagree	12	18.8	18.8	98.4
	Strongly Disagree	1	1.6	1.6	100.0
	Total	64	100.0	100.0	

## Appendix 6 (continued)

Question 18: Improved equipment maintainability

		Frequency	Percent	Valid Percent	Cumulative Percent
	Agree Strongly	11	17.2	17.2	17.2
	Agree	24	37.5	37.5	54.7
	Neither Agree nor Disagree	14	21.9	21.9	76.6
	Disagree	13	20.3	20.3	96.9
	Strongly Disagree	2	3.1	3.1	100.0
	Total	64	100.0	100.0	

**APPENDIX 7: Comparison of means barchart**



## **Glossary of Terms**

**Best Operating Practice (BOP):** The accepted and documented way of doing something.

**Condition Monitoring:** The measurement and recording of something that is evidence of deterioration in the condition of an item.

**Decision/Logic Diagram:** A graphic display of the decision process, in which answers to an ordered sequence to a yes or no questions link to the most appropriate maintenance tasks to the failure being analysed.

**Formal Failure Analysis (FFA):** A fault analysis or identification process used to establish root causes of problems.

**Functional Failure:** The inability of an item or equipment to meet a specified condition.

**Maintenance Schedule:** A planned job that is performed on a predetermined frequency to enhance the reliability of equipment.

**Multidisciplinary Team (MDT):** A group of people responsible for operating, supporting and managing self-contained operating process.

**Potential Failure:** A condition that indicates that a functional failure is about to take place.

**Resistance to Failure:** The durability of the item or equipment to operate satisfactorily.

**Significant Item:** An item whose functional failure has major safety, environmental or economic consequences.

**Shift Based Teams (SBT):** A group of people responsible for operating and supporting a self-contained operating process at shift-level.

**Small Business Units (SBU):** Same as Shift Based Team (above).

**Total Productive Maintenance/Manufacturing:** Total Productive Maintenance is a company wide improvement strategy focusing on equipment management involving all employees aimed at improving productivity, quality, safety, employee morale, cost and bottom line results.