# The Impact of Total Productive Maintenance (TPM) on manufacturing performance at the Colt section of DaimlerChrysler in the Eastern Cape

By

**Mfowabo Ncube (20525376)**

Submitted in partial fulfillment of the requirements for the degree of

**Masters in Business Administration**

**At Nelson Mandela Metropolitan University (NMMU) Business School**

**Research Supervisor: Prof J. J. Pieterse**

**22 November 2006**

## Declaration

"I, Mfowabo Ncube, hereby declare that:

- This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

- This dissertation is being submitted in partial fulfilment of the requirements for the degree of Masters in Business Administration.

- This dissertation is the result of my independent work/investigation, except where otherwise stated. Other sources are acknowledged by complete referencing. A reference list is attached.

- I hereby give consent for my dissertation, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organisations."

Signed: ……

Date: 22 November 2006

## Acknowledgements

There are many individuals who have assisted in different ways with the completion of this work. I would like to thank all those who have encouraged, motivated and assisted me in completing this research paper as scheduled.

In particular, I acknowledge:

- **GOD** for giving me the capacity to complete this degree.
- Prof J.J. Pieterse, for the professional and constructive manner with which he guided and supported me.
- The management and staff of Colt Production facility (DCSA) for allowing me the opportunity to undertake this study and the assistance provided in making the necessary information available.
- My employer, Mondi Packaging South Africa, for believing in me.
- My family for their patience and understanding.
- My friends for their support.

**Abstract**

Today's successful manufacturing organisations require a significant competitive advantage, hence the need to implement and develop a Total Productive Maintenance (TPM) strategy. This research paper addresses the impact of TPM on manufacturing performance at the Colt production facility (DCSA). A literature survey was undertaken into the elements and benefits of TPM. Questionnaires were also sent to all levels of people at the Colt production facility for their views on TPM and the impact, they believe, it has had on manufacturing performance. In conclusion, this research paper has also led to the development of recommendations to improve TPM activities at the Colt production facility.

From the research, it was shown that top management support for TPM activities is needed and that training is an essential factor for TPM's success in improving manufacturing performance.

*Keywords:*
Total Productive Maintenance, Manufacturing Performance, Total Quality Management, Continuous Improvement.

## Table of Contents

**Chapter 2: The theory of TPM: Elements and overview**

**Chapter 3: Research design and methodology**



**Chapter 4: Research findings**

**Chapter 5: Conclusion and recommendations**

## List of figures

**List of Tables**

# CHAPTER 1

# INTRODUCTION AND PROBLEM STATEMENT

## 1 Introduction

Industrial manufacturing of products is facing accelerating changes of pace in technology and market demands (Jackson, 2000). In recent years, manufacturing industries have also experienced unprecedented degrees of change in management, process technology, customer expectations, supplier attitudes and competitive behaviour (Beach, Muhlemann, and Price 2000 p7). The above statements show that industries which have manufacturing systems, with high dependability, have implemented world-class manufacturing strategies/techniques such as Total Productive Maintenance (TPM). Change is now a permanent feature of the business environment and organisations, which adapt to this new environment, are more likely to gain a significant competitive advantage.

Total Productive Maintenance (TPM) is a strategic change management approach that has considerable impact on the internal efficiency of manufacturing organisations, both in the West and in Japan (Jackson, 2000). TPM is an organisation-wide strategy to increase the effectiveness of production environments, especially through methods for increasing the effectiveness of equipment.

"TPM is considered by many writers to be an indispensable contribution to lean production supporting just-in-time (JIT) manufacture and total quality management (TQM), and has been shown as an essential pillar alongside JIT and TQM for companies seeking world-class manufacturing status." (Bamber, Sharp and Hides 1999:162). Therefore, an assessment of the impact of Total Productive Maintenance (TPM) on manufacturing performance by the researcher is appropriate and essential for the motor vehicle assembly industry and, ultimately, the economy of South Africa.

## 1.1 Problem statement

The motor vehicle assembly industry is technically one of the most competitive and sophisticated industries. Motor vehicle assembly industries are on the leading edge when it comes to developing new techniques to find better and improved ways to build cars, in an effort to make them affordable and with better perceived quality than their competitors (Womack, Jones & Roos, 1990:11).

To achieve a competitive advantage, organisations have implemented various world-class manufacturing techniques/strategies. One of these is TPM, which is part of lean manufacturing (Rubrich & Watson, 2000).

TPM goals are:

- zero breakdowns;
- zero abnormalities;
- zero defects; and
- zero accidents. (Nakajima, 1989).

The path to this ideal situation is continuous improvement that requires total commitment of everyone in the organisation, from operators to top management. With this in mind, the researcher has, therefore, focused on DaimlerChrysler South Africa's operation with a view to determining whether the TPM concept is a viable route to follow or another temporary solution. This leads to the question, which constitutes the main problem of this research paper:

- **What is the impact of Total Productive Maintenance (TPM) on manufacturing performance at the Colt section of DaimlerChrysler South Africa (DCSA)?**

## 1.2 Statement of sub-problems

In order to develop a strategy to conduct this research in a systematic manner, a number of sub-problems were highlighted to enable the researcher to find an appropriate solution to the main problem.

The sub-problems are:

- What does literature reveal about the impact of TPM on the manufacturing performance of an organization?
- To what extent has TPM been implemented at the Colt section of DCSA?
- What is the extent of the cost savings as result of TPM's implementation at the Colt section of DCSA?
- What are the limitations of TPM at the Colt Section of DCSA?
- What will enhance the impact of TPM on fast delivery and on-time delivery at the Colt Section of DCSA?

## 1.3 Objectives of the research

The objectives of this study are:

- Identify the elements of TPM and its guidelines for overall plant performance.
- Establish the influence of TPM on productivity, employee development, quality improvement and organisational change.
- Analyse the past and current status of TPM on manufacturing performance measurements.
- **Understand the performance of the equipment (what is being achieved in overall equipment efficiency terms and what is the reason for non-achievement).**

## 1.4 Delimitations of the research

This research paper will be limited to DCSA's Colt Section in the Eastern Cape and the delimitations are:

### 1.4.1 Management level

The research will be limited to key management (managers responsible for the engine department), team leaders (responsible for the operators) and operators (shop floor employees).

### 1.4.2 Business unit

The selected department is one of the business units of DCSA. There are over 230 people employed at the Colt Section/ Department.

### 1.4.3 Geographical demarcation

The empirical component of this study is limited to the Colt Section of DCSA in the Eastern Cape, East London.

## 1.5 Definitions of concepts

For the purpose of the study, the following meanings are associated with concepts in the title and the problem statement.

### 1.5.1 Autonomous maintenance

Autonomous maintenance is the best practice of operators taking ownership of their equipment and sharing the responsibility for its maintenance with the maintenance department (Nakajima, 1989). The consequence of a maturing autonomous maintenance programme is the transfer of routine maintenance skills from the technician to the TPM operators (Rich, 1999:312). This process of transition frees an element of the maintenance role each time these skills are passed from technician and includes the transfer of routines that hold low levels of value-add when this type of work is passed on to operators who benefit from improved ownership of the production process when they are empowered through greater control.

### 1.5.2 Continuous improvement (CI)

This means improving performance with many small, incremental improvement steps. In Japan, continuous improvement is known as kaizen and involves everyone. It implies a never-ending cycle of repeatedly

questioning and requisitioning of the basic workings of an operation (Russell & Taylor, 2003).

### 1.5.3 Total Productive Maintenance (TPM)

TPM's strict definition has five steps, (Nakajima, 1998):

- Maximising equipment effectiveness through optimisation of equipment availability, performance, efficiency and product quality;
- Establishing a maintenance strategy (level and type of classical preventive maintenance) for the life of the equipment;
- Includes all dependants such as the planning, the user and the maintenance department;
- Involving all staff members from top management to shop floor workers; and
- Promoting improved maintenance through small-group autonomous activities.

TPM also encourages radical changes such as:

- Flatter organisational structures, i.e. fewer managers and empowered teams;
- Multi-skilled workforce; and
- Rigorous re-appraisals of the way things are done, often with the goal of simplification (Liker, 2004).

TPM has two main aspects:

- A structured approach which uses a number of tools and techniques such as Kaizen, 5S, reactive, preventative, reliability-centred and predictive maintenance to achieve very effective plants and machinery and to measure its effectiveness; and

- A philosophy, which is based upon the empowerment and encouragement of factory floor-based personnel from all areas (Davis & Willmott, 1999).

### 1.5.4 "5S" method of equipment maintenance

This is a prerequisite for the implementation of TPM because of the order and logic it brings to the workplace. 5S is defined as the best practice of implementing and maintaining good and structured house keeping. It consists of:

- getting rid of unnecessary items;
- a place for everything in its proper place,
- workplace cleanliness;
- establishing housekeeping standards; and
- maintaining standards in a disciplined way. (Rubrich and Watson, 2000).

### 1.5.5 Lean manufacturing

This is a way of thinking that focuses on making the product flow through value-adding processes without interruption (one-piece flow), a "pull" system that cascades back from customer demand by replenishing only what the next operation takes away at short intervals, and a culture in which everyone is striving continuously to improve (Womack and Jones, 2003).

### 1.5.6 Just-in-time (JIT)

Just-in-Time is defined as a set of principles, tools and techniques that allow a company to produce and deliver products in small quantities, with short lead times, to meet specific customer needs (Liker, 2004:23).

### 1.5.7 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness is defined as a gauge system on equipment that measures quantities such as uptime, units produced, and sometimes even the production speed. This technique works to eliminate the six big

losses indicated by Nakajima, as down time (caused by equipment failure, set-up and adjustment), speed losses (owed by idling, minor stoppage and reduced speed) and defects (caused by process defects and reduced yield) (Nakajima, 1989).

### 1.5.8 Total Quality Management (TQM)

Total Quality Management is defined as a business-wide philosophy which includes changing attitudes, working practices, values and the overall method of operation of the company. Its overall aim is to improve continuously the operating performance of the business, thus providing better customer service and increased profitability (Davis, 1995:11).

### 1.5.9 Productivity

Productivity is a measure of the effective use of resources, usually expressed as the ratio of output to input. A productivity ratio can be computed for a single operation, department, an organisation or an entire country. For non-profit organisations, higher productivity means lower costs; for profit-based organisations, productivity is an important factor in determining how competitive a company is (Stevenson, 2002:51).

## 1.6 Significance of the research

Increased globalisation is forcing manufacturing organisations to implement world class manufacturing techniques through shorter product life-cycles, increased automation, new technology, more production systems and production strategies.

This research paper focuses on gaining insights into the impact of Total Productive Maintenance (TPM) on the manufacturing performance at the Colt Section of DCSA.

On the basis of this research, it should be useful to:

- Top management who address the impact of TPM on productivity, employee development, quality improvement and organisational change;

- Team leaders and trainers who prepare and educate parties who are focused on the three constructs of TPM such as TPM strategies, TPM teams and TPM processes; and
- Team leaders and team members who should continuously focus on improving their processes.

From this study, recommendations will be developed as guidelines to overcome problems previously experienced.

## 1.7 Research methodology

The study comprises of a literature study and an empirical study.

### 1.7.1 Literature study

The literature study was done in order to establish key concepts, which relate to TPM. The results of the literature survey were used as a guideline to determine the impact/effectiveness of TPM on manufacturing performance at the Colt Section.

The existing theory relating to TPM was analysed from secondary sources and related sources such as:

- Internet sites and the web pages of different companies and organisations;
- Textbooks and other published material directly or indirectly related to the problem area; and
- Academic as well as organisational journals and newsletters relevant to the problem (Ghauri & Gronhaug, 2002:77).

As Churchill (1999:215) stated: “Do not bypass secondary data. Begin with secondary data, and only when the secondary data is exhausted or shows diminishing returns, proceed to primary data”.

### 1.7.2 Empirical study

Empirical study implies measurements, and measurements are defined as rules for assigning **numbers** (or other numerals) to empirical properties. Thus, **numbers** are amenable to quantitative analyses, which may reveal new information about the items studied (Ghauri & Gronhaug, 2002:64).

The empirical study consists of:

- Interviews, observations and surveys (questionnaires) at the Colt Section of Daimler Chrysler.

The interviews, observations and surveys (questionnaires) enabled the researcher to:

- Make direct contact with current team leaders and team members to assess their expectations with regards to TPM.
- Observe the impact of highly visible measures of performance such as:
    - The improvement of overall effectiveness;
    - The number of improvements made;
    - The amount of time spent on TPM activities;
    - The amount of training and new skills obtained;
    - The improvement of the workplace environment; and
    - Obtain immediate information on the current status of TPM from the team members and team leaders of the selected department.

## 1.8 Key Assumptions

The key assumption is that the literature study, combined with the results of the empirical study, will provide insight into the impact of TPM on the performance of the selected section of DCSA, thereby improving the overall manufacturing strategy of the organisation.

## 1.9 Contents of the final report

The research paper is arranged as follows:

Chapter 1: Introduction and problem statement

Chapter 2: The theory of TPM: Elements and Overview

Chapter 3: Research design and methodology

Chapter 4: Research findings

Chapter 5: Conclusion and recommendations

# CHAPTER 2

## THE THEORY OF TPM: Elements and overview

### 2 Introduction

This chapter examines the concept of Total Productive Maintenance (TPM) and the role it plays in productivity, employee development, quality improvement and organisational change. TPM is a manufacturing-led initiative that emphasises the importance of:

(a) people with a “can do: and continual improvement attitude; and

(b) production and maintenance personnel working together in unison (Rich, 1999).

According to Nakajima (1998), the word "total" in "total productive maintenance" has three meanings that describe the principal features of TPM:

- Total effectiveness indicates TPM's pursuit of economic efficiency or profitability which includes productivity, cost, quality, delivery, safety, environment, health and morale.
- Total maintenance system includes maintenance prevention and maintainability improvement as well as preventive maintenance: It refers to "maintenance-free" design through the incorporation of reliability, maintainability and supportability characteristics into the equipment design.
- Total participation of all employees includes autonomous maintenance by operators through small group activities: The small group activities promote planned maintenance through “motivation management”.

In essence, TPM seeks to integrate the organisation to recognize, liberate and utilize its own potential and skills (Lee, 2002).

## 2.1 Origin and development of TPM

TPM is an innovative concept which originated in Japan (1971) in response to the maintenance and support problems encountered in manufacturing environments and was an equipment management strategy designed to support the Total Quality Management strategy. According to the Japanese Institute of Plant Engineers (JIPE), TPM is defined as a team-based maintenance strategy, designed to maximise equipment effectiveness by establishing a comprehensive maintenance production system covering the entire life of equipment related fields (planning, use and maintenance) and involving everyone, from top management executives to the production floor operators.

Seichi Nakajima is credited with defining the fundamental concepts of TPM and seeing the procedure implemented in hundreds of plants in Japan with the key concepts being autonomous maintenance performed by the machine operators together with small-group problem-solving activities (Nakajima, 1989).

The modern TPM approach reflects a concern to integrate all the necessary business departments, which affect the process of maintenance management in such a manner that the roles, responsibilities, and care of the assets are optimised throughout its service to the manufacturing company (Rich, 1999).

## 2.2 World-class manufacturing and TPM

During the last decade, many manufacturing companies have made extensive use of benchmarking activities to determine “best in class” performance for management practices (Todd, 1995). These management practices are termed world-class manufacturing concepts and are:

- Total Quality Management (TQM),
- Total Productive Maintenance (TPM),
- Just-In-Time Production (JIT),
- Total Employee Involvement (TEI), and
- Continuous Quality Improvement (CQI).

These concepts cover all the components of an effective manufacturing management system.

The following brief descriptions are some of the world-class manufacturing concepts that will not be covered in detail in this research paper.

- Total employee involvement is an approach that includes employees in the decisions that affect the production system. This principle of world-class manufacturing builds on the belief that the best source of information on the production process is the employee who works within the process. Employees, with the proper training, tools and guidance, are empowered to improve the production system.

- Continuous Quality Improvement (CQI) requires that all the world-class manufacturing concepts be continuously improved over their entire life cycle. The main aim of CQI is long term, incremental improvements that provide evolutionary performance gains.

## 2.3 TQM and TPM

TPM closely resembles the popular Total Quality Management (TQM) programme. Many of the tools, such as employee empowerment, benchmarking and documentation, used in TQM are used to implement and optimise TPM. The similarities between the two concepts are:

- Total commitment to the programme by upper management level is required in both programmes. Management should cultivate a culture of participation, autonomy and overall direction for the work that is clearly targeted and engaging. The job of a manager is to consult, consultant, mentor and coach employees in order to:
    - increase their task-relevant knowledge and skills; and
    - formulate creative, unique and appropriate performance strategies that generate synergistic process gains.

- Employees must be empowered to initiate corrective actions. Empowerment refers to a change strategy with the objective of improving the ability of the individual and the organisation to act (Schultz, H., Bagraim *et al*. 2003:151). Employee empowerment is desirable in order to create high levels of commitment amongst the concerned personnel. For this, management, within the overall aims of the organisation, must involve employees in setting challenging targets and specifying how to achieve them.
- Communication must be of utmost importance. Communication is an exchange of information and understanding between two or more persons or groups. Employees must be encouraged to set measurable and attainable goals. Employee training should focus on appropriate multi-skills and knowledge. The objective throughout the organisation should be of continual improvement.

The above shows that TPM is total quality aimed at improving the condition and performance of the facilities that the businesses use to perform processes. Through the TPM teams, good and effective channels of communication are established and all levels of employees are given the opportunity to put forward their views and ideas.

TPM teams become the basic unit of organisational learning and employees experience a sense of autonomy and meaningfulness in their work, which enables them to participate in goal setting, problem solving, decision making and change facilitation.

It is likely that the use of TPM, to improve equipment performance and increase the skills of workers, could be an additional factor supporting TQM and explaining competitive advantage. Therefore, TPM indirectly improves manufacturing performance by supporting TQM efforts (Mcklone et al, 1998).

## 2.4 Lean manufacturing and TPM

Lean manufacturing techniques are typically considered to be synonymous with the Toyota Production System (TPS). According to Todd (1995), lean

manufacturing is a collection of concepts and activities that strive to eliminate all waste in the production system. Simply put, lean manufacturing gets “the right parts to the right place at the right time with zero waste”. The two most common forms of waste addressed by lean manufacturing are defects and excessive inventory.

Todd (1995) also states that lean manufacturing improves the effectiveness and efficiency of the manufacturing system by increasing the system’s flexibility to accommodate variety in the product mix and variation in throughput, while focusing on optimising the overall system.

From the above discussion, it should be seen that the components of the Toyota Production System (TPS), as created by Taiichi Ohno, can be aligned with the primary goals of Total Productive Maintenance (TPM). Figure 1.1 shows the basic features of the TPS and their relationship to the six process losses of TPM as described by Hamacher (1996)

**Figure 2.1: Toyota Production System and TPM**

| TPS \ TPM | Breakdowns | Setup and adjustments | Idling and minor stops | Reduced speed | Process defects | Startup losses |
|---|---|---|---|---|---|---|
| Implementing flow processes | X | | | | | |
| Eliminating defects | | | | | X | X |
| Stockless production | X | X | | | | |
| Reduced lot size | | X | | | | |
| Quick setup | | X | | | | |
| Standard cycle times | X | X | X | X | X | |
| Standard sequence | X | X | X | X | X | |
| Standard idle time | X | X | X | X | X | |
| Visual control | X | X | X | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Improved operability | **X** | **X** | | | | |
| Improved maintainability | **X** | | | | | |

*Source*: Hamacher (1996)

## 2.5 Maintenance concepts

A maintenance concept is defined as the set of various maintenance interventions (preventive, corrective, reliability-centred, condition-based, etc) and the general structure in which these interventions are brought together (Puyvelde, 1999).

An explanation of some maintenance concepts is as follows (Wireman, 1991):

### 2.5.1 Preventive maintenance (PM)

In this type of maintenance, items are replaced or restored to their optimal working condition before a failure is allowed to occur. This may be based on scheduled, time-based or condition-based PM. The schedule is drawn up on the supplier's recommendation, which usually only considers limited knowledge of the actual conditions. Therefore, it is better to draw from experience.

### 2.5.2 Reliability-centred maintenance (RCM)

RCM is a process used to decide what must be done to ensure that any physical system or process continues to accomplish whatever its users want it to do. What is expected is defined in terms of primary performance parameters, such as output, throughput, speed, range and capacity. Sometimes, the RCM process defines minimum standards, which the users can tolerate in terms of risk (relating to safety and adverse environmental-impact), quality (in terms of precision, accuracy, consistency and stability), control, comfort, economy and customer service.

RCM operates through the use of analysis techniques such as:

- Failure modes effect analysis (FMEA);

- Cause and effect analysis;
- Risk analysis;

Failure management options include PM, predictive maintenance, and run-to-failure, which can result in changing the design of the system and/or the way it is operated (Moubray, 2000).

### 2.5.3 Condition-based maintenance (CBM)

Also called predictive maintenance, CBM forecasts failures through analysis of the condition of the equipment. A number of monitoring techniques are used such as vibration monitoring, thermography, oil analysis and ferrography.

Each of these methods is designed to detect a specific category of faults. For example vibration monitoring can detect wear, imbalance misaligned components, loosened assemblies or turbulence in a plant with rotational or reciprocating parts. The design may be modified to achieve improved reliability, enhanced maintainability, minimum maintenance resource requirements and so even eliminate the need for routine maintenance.

## 2.6 Maintenance performance indicators

According to Campbell and Jardine (2001), the commonly used maintenance performance indicators are measures of:

- Equipment performance such as availability, reliability and OEE;
- Process performance such as the ratio of planned and unplanned work, as well as of schedule; and
- Cost performance such as labour and material costs of maintenance.

## 2.7 TPM targets

TPM targets should reflect the ongoing transactions with the customer (quality, cost and delivery criteria) as well as ongoing measures which affect

the productivity within the factory (productivity, safety and morale). These issues are termed “PQCDSM'” (Nakajima, 1998).

**Table 2.1:**

TPM targets (Venkatesh, 2005) contribute to:

| | |
|---|---|
| Motives of TPM | ✓ Adoption of life approach for improving the overall performance of production equipment.<br>✓ Improving productivity by highly motivated workers which is achieved by job enlargement.<br>✓ The use of voluntary small group activities for identifying the cause of failure, possible plant and equipment modifications. |
| Uniqueness of TPM | The major difference between TPM and other concepts is that the operators are also involved in the maintenance process. |
| TPM objectives | a) Achieve zero defects, zero breakdown and zero accidents in all functional areas of the organisation.<br>b) Involve people at all levels of the organisation.<br>c) Form teams to reduce defects and self maintenance. |
| Direct benefits of TPM | - Increase productivity and obtain a minimum of 80% OPE (Overall Plant Efficiency) and minimum of 90% OEE.<br>- Rectify customer complaints.<br>- Reduce manufacturing cost by 30%.<br>- Satisfy customers' needs by 100% (delivering the right quantity at the right time, in the required quality.<br>- Reduce accidents.<br>- Follow pollution control measures. |
| Indirect benefits of TPM | ▪ Higher confidence levels among the employees.<br>▪ A workplace which is clean, neat and attractive.<br>▪ Favorable change in the attitude of the operators.<br>▪ Achievement of goals by working as a team.<br>▪ “Ownership” of the machine by workers. |

## 2.8 Measurement of TPM effectiveness

From a generic perspective, TPM can be defined in terms of overall equipment effectiveness (OEE) (Dal et al, 2000). The goal of TPM is to maximise equipment effectiveness. OEE provides an effective way of measuring and analysing the efficiency of a single machine/cell or an integrated manufacturing system. OEE is also used as a driver for improving performance of the business by concentrating on quality, productivity and machine utilisation issues. It is aimed at reducing non-value adding activities, often inherent in manufacturing processes.

### 2.8.1 TPM and Teams

Modern maintenance practice and world-class manufacturing operations are aimed at utilising the knowledge and resources of personnel from across many manufacturing functions. This is termed cross-functional teams (CFT). TPM is a discipline founded on the principle of involvement and according to Nakajima (1988), TPM is based on the three interrelated concepts:

- Maximizing equipment effectiveness;
- Autonomous maintenance by operators; and
- Small group activities.

Hence, OEE may be considered as the combining of the operation, maintenance and management of manufacturing equipment and resources (Dal et al, 2000). Clifford and Sohal (1998), report that one of the recognised benefits of a strong team led organisation is “increased productivity through improved machine efficiency, improvements in up-time and improved preventive maintenance”.

TPM teams can be developed using the model of Tuckman and Jenson (1997) who outlined the four key stages as:

- Forming;
- Storming;
- Norming; and

- Performing.

The authors advocate developing OEE cross-functional teams using a conceptual model, based on seven factors, for successful implementation of high performance teams (Castka *et al*., 2001). The model comprises:

1) Organisational impact;
2) Defined focus;
3) Alignment and interaction with external entities;
4) Measures of performance;
5) Knowledge and skills;
6) Need of the individual; and
7) Group culture.

The above shows that cross-functional teams “pull” together in order to improve the overall manufacturing performance of the organisation. Teamwork can be measured in terms of the indices of information sharing, support, shared vision and orientation to task.

Research indicates an above 38 per cent reduction in defects and a 20 per cent improvement in productivity and higher customer service ratings as well as monthly sales (Schultz, H., Bagraim *et al*. 2003:97).

### 2.8.2 Purpose of OEE

Firstly, the OEE measure can be used as a benchmark for measuring the initial performance of a manufacturing plant in its entirety. In this measure, the initial OEE measure can be compared with the future OEE values, thus quantifying the level of improvement made.

Secondly, an OEE value, calculated for one manufacturing line, may be used to compare line performance across the factory, thereby highlighting any poor line performance.

Thirdly, if machines process work individually, an OEE measure can identify which machine performance is worst and therefore indicate where to focus TPM resources (Nakajima, 1989).

### 2.8.3 The six big losses

Chronic and sporadic disturbances in the manufacturing process result in different kinds of waste or losses. These can be defined as activities which absorb resources and create no value. The objective of OEE is to identify these losses. It is a bottom-up approach where an integrated workforce strives to achieve overall equipment effectiveness by eliminating the six big losses (Nakajima, 1988).

These six big losses are grouped into three major categories:

- Downtime;
- Speed losses; and
- Defect losses.

Nakajima (1988) defines these six big losses as shown in the table below.

**Table 2.2: The six big losses**

| **Loss categories** | **Six big losses** |
|---|---|
| Downtime<br>(Lost availability) | Equipment failures<br>Set-up and adjustments |
| Speed losses<br>(Lost performance) | Idling and minor stoppages<br>Reduced speed operation |
| Defect losses<br>(Lost quality) | Scrap and rework<br>Start-up losses |

*Loss category 1* – **Downtime**

Downtime refers to the time when the machine should be running but stands still. Downtime includes two main types of loss: Equipment failures as well as set-up and adjustments.

- Equipment failures: These losses of operating time result from the deterioration of equipment, and sudden failures in the operating and control mechanisms of equipment. This form of lost time is compounded by the need to keep or procure spaces and anytime the factory labour is not utilised whilst the restoration of the machine takes place.

  - ✓ Changeover, set-up and adjustment losses: These losses are created through the procedures, methods and technology required to change a machine from one product to another. The production schedule will dictate the number of changes required. However the actual process of changing the machine over is the loss which must be minimised.

*Loss Category 2* – **Speed losses**

A speed loss is when the equipment is not running at its maximum designed speed. Speed losses include two main types of loss: Idling and minor stoppages and Reduced speed operation.

- Idling and minor stoppages: When a machine is not running smoothly and at a stable speed, it will lose speed and obstruct a smooth flow. The idling and stoppages in this case are not caused by technical failures but by small problems such as parts that block sensors. Although the operator can easily correct such problems, frequent halts can dramatically reduce the effectiveness of the equipment.

  - ✓ Reduced speed operation: This refers to the difference between the actual operating speed and the equipment's designed speed (also referred to as nameplate capacity). The goal is to eliminate the gap between the actual speed and the designed speed. Significant losses from reduced speed operation are often neglected or underestimated.

Loss category 3 – **Defect losses**

A defect loss means that the equipment is producing products that do not fully meet the specified quality characteristics. Defect losses include two major types of loss: Scrap and rework, and start-up losses.

- ✓ Scrap and rework: These losses reduce the performance of the manufacturing process and can also include a secondary consumption of manufacturing time as the product is re-worked. This loss includes many additional costs including labour and materials. Products which cannot be re-worked are therefore scrapped and this incurs costs of collecting and disposing of the materials from the factory (Rich, 1999). The goal should be for zero defect, i.e. to make the product right the first time and every time.

- ✓ Start-up losses: These losses occur when production is not immediately stable at the equipment start-up, resulting in the first products not meeting customer specifications.

Jeong and Philips (2001) argue that loss classification schemes are ultimately tied to the industry types and that when assessing an organisational OEE, it is not necessarily important that Nakajima's (1988) six big losses are used explicitly or definitively. However, it is necessary for an organisation to develop its own classification framework for the losses. These losses should be associated with the components of availability, performance and quality.

Based on their research, Jeong and Philips (2001) propose the following classification of losses in capital-intensive industry:

- Non-scheduled time duration for which equipment is not scheduled to operate - this time may include holidays and leave;
- Scheduled maintenance time - this is time spent for preventive maintenance of equipment;

- Unscheduled maintenance - this is time spent for breakdown;
- Time spent on research and development;
- Set-up and adjustment time - this is time spent for set-up and adjustment for operation;
- Work in Progress (WIP) starvation time for which equipment is operating when there is no WIP to process;
- Idle time without operator - time for which WIP is ready, however, there is no operator to available;
- Speed loss - time loss due to the equipment that is operating under standard speed; and
- Quality loss - time for which equipment is operating for the unqualified products.

*OEE analysis*

OEE is measured in terms of the six big losses, which are essentially a function of the availability, performance rate and quality rate of the machine, production line or factory.

**OEE** (%) = availability (%) x performance rate (%) x quality rate (%).

- The availability rate measures the total time that the system is not operating because of breakdown, set-up and adjustment, and other stoppages. It indicates the ratio of operating time to the planned time available. Planned production time (or loading time) is separated from theoretical production time and measures unplanned downtime in the equipment – in this definition, unavailability would not include time for preventive maintenance.

$$\text{Availability rate} = \frac{\text{Operating time} - \text{Downtime}}{\text{Total operating time}}$$

- The performance rate measures the ratio of actual operating speed of the equipment – the ideal speed minus speed losses, minor stoppages and idling.

$$\text{Performance rate} = \frac{\text{Total output}}{\text{Potential output at rated speed}}$$

- The quality rate only takes into consideration the quality losses (number of items rejected due to quality defects) that happen close to the equipment, not the quality losses that appear downstream.

$$\text{Quality rate} = \frac{\text{Good output}}{\text{Total output}}$$

Nakajima (1988) suggested that the ideal values for the OEE component measures are: Availability in excess of 90 per cent, performance in excess of 95 per cent, and quality in excess of 99 per cent. These figures would result in an OEE of approximately 85 per cent for world-class manufacturing organisations and this figure is considered as a good benchmark for a typical manufacturing capability. Kotze (1993), on the other hand, argues that an OEE figure of greater than 50 per cent is more realistic and therefore more useful as an acceptable target.

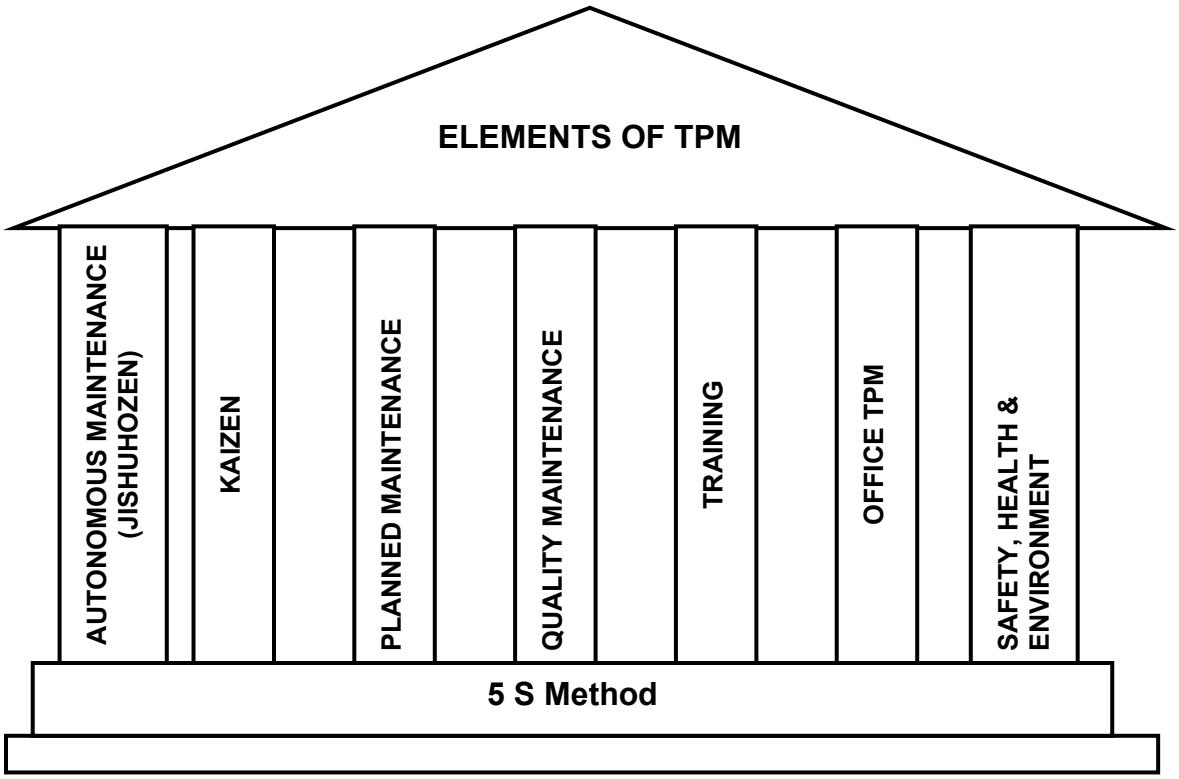
By utilising largely existing data, such as preventative maintenance, material utilisation, absenteeism, accidents, labour recovery, set-up and changeover data, the OEE measure could provide topical information for daily decision making. OEE also takes into account process improvement initiatives and incorporates practical management tools (Dal *et al*, 2000).

The OEE measure is, therefore, the most appropriate means of determining the true value-add of the conversion process as a system and the extent to which the zero-loss factory has been realised.

## 2.9 The operational elements of TPM

TPM experts Nakajima (1988), Hartmann (1992) and Wireman (1991) agree that the aim of TPM activities is to improve productivity, quality costs, cost of products, delivery and movement of products, safety of operations and morale of those involved (**PQCDSM**). Furthermore, these experts consider the elements of TPM to be as shown in figure 1.

**Figure 2.2: Operational elements/Pillars of TPM**




Source: **Venkatesh (2005)**

### 2.9.1 5S Method

The 5S approach to production area discipline is a structured method of control and originates from Japan. Each of the five elements of the process is spelt with an “s” in Japanese. In this instance, control means cleaning and organising the workplace to help the teams to uncover problems. Making

problems visible is the first step of improvement. The following explains the 5S terms and their English translations (Rubrich & Watson, 2000):

- *Seiri* (Sort out): This means sorting and organising the items which are critical, important and frequently used. For this step, the worth of the item should be decided based on utility and not cost.
- *Seiton* - Organising: This means placing things in such a way that they can be easily reached whenever they are needed.
- *Seiso* - Cleaning: Keeping things clean and polished. No trash or dirt is allowed in the workplace.
- *Seiketsu* - Standardising: Maintain cleanliness after cleaning - perpetual cleaning.
- *Shitsuke* – Self discipline: Commitment, a typical teaching and attitude towards undertaking to inspire pride and adherence to standards established for the above four elements/steps.

5S approach methods improve safety, work efficiency, productivity and establish a sense of ownership.

The benefits of 5S approach include:

- The psychological impact of a clean and tidy environment on team morale;
- The ability to spot non-conformances of materials, tools and equipment;
- Less downtime machinery due to material shortages,
- Improvements in the efficiency of the area; and
- Improved productivity, less stock held in the area and less expediting by the team to find materials (Rich, 1999).

### 2.9.2 Autonomous Maintenance (*Jishu Hozen*)

Autonomous maintenance creates a system of regular preventative maintenance cycles by the team to support the conversion process by

cleaning, lubricating and inspecting the assets under the control of the team in a pre-defined and timely manner. The benefits of this activity include the transfer of vital skills from maintenance technicians to the teams, the creation of discipline and control in the organisation and maturation of the team-development process.

With each cycle of improvement and learning, competence grows and the continual change process creates a series of performance improvement ratchets. These ratchets allow firm foundations of competence to be established by the team and create vital platforms for future systematic change in the organisation (Rich, 1999:309).

### 2.9.3 Kaizen

"Kai" means change, and "Zen" means good (for better). Kaizen is for small improvements, and is carried out on a continual, basis involving all people in the organisation. The principle of Kaizen is that a very large number of small improvements are more effective in an organisational environment than a few improvements of large value. This element of TPM is aimed at reducing losses in the workplace that affect efficiencies. In essence, Kaizen pursues efficient equipment, operator, material and energy utilisation, which is extremely good for productivity and aims at achieving substantial effect.

### 2.9.4 Planned maintenance

In this element of TPM, the following is realised:

- Trouble-free machines and equipment, producing defect free products for total customer satisfaction;
- Optimum availability of machines;
- Optimum maintenance cost and reduced spares inventory; and
- The improved reliability and maintainability of machines.

This element breaks maintenance down into its types which were defined earlier and the efforts of the organisation evolve from a reactive to a proactive method.

### 2.9.5 Quality maintenance

This element is aimed towards the customer delight through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like focused improvement. The organisation gains understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, and then move to potential quality concerns. Transition is from reactive to proactive (quality control to quality assurance).

### 2.9.6 Training

The fifth element aims at having multi-skilled and revitalised employees whose morale is high and are eager to come to work and perform all the required functions effectively as well as independently.

### 2.9.7 Office TPM

Office TPM must be followed to improve productivity and efficiency in the administrative functions by identifying and eliminating losses. This includes analysing processes and procedures which increase office automation. Office TPM addresses the following major losses:

- Processing losses;
- Cost losses in procurement, accounts, marketing and sales which lead to high inventories;
- Customer complaints, due to logistics; and
- Communication channel breakdown, telephone and fax lines.

### 2.9.8 Safety, health and environment

In this element, the focus is on creating a safe workplace and a surrounding area that is not damaged by the organisation's processes or procedures. This pillar plays an active role in each of the other pillars.

Maggard and Rhyne (1992) concur with the views expressed by Nakajima (1988) on the elements of TPM and add the aspect of safety. They insist that assuring safety and preventing any adverse environmental impacts are important priorities for TPM.

According to Rich (1999), the most fundamental objective of the TPM programme is to establish a safe working environment and a safety procedure which regulates the behaviour of personnel in the factory. A TPM system must, therefore, include the development and evaluation of the safety record for the factory and the regular auditing of the health of the team working structures in the factory.

## 2.10 Traditional measures of manufacturing performance

The traditional measures of manufacturing performance focused on three issues (Rich, 1999):

- Asset utilisation which was targeted at 100 per cent or the highest possible level to ensure that the production time was maximised and that a stream of products could be placed in the distribution channel to the customer.
- Labour utilisation was also set at 100 per cent or the maximum to ensure that the legions of production personnel were occupied making products for the amount of time they spent in the factory. This was often linked to the financial remuneration of employees through the piece rate system and focused the minds of everyone in the factory on “output”.
- Low material costs and usage: This meant that the costs of materials were kept low by maximising the use of all materials within the

conversion process and through adversarial purchasing regimes (buying from the lowest piece-part-price supplier).

These traditional measures of manufacturing performance are counter to the objectives of TPM. It allows for a culture to be developed which is insular and detached from the commercial requirements of the business (Rich, 1997).

The traditional measures must be changed to measures which are aligned to the conversion process with the commercial goals of the organisation so that the organisation becomes a world-class manufacturing company. According to Todd (1995:3), world-class simply means being the best and "best" can be in terms of:

- Product design and performance:
- Quality and reliability:
- Least manufacturing cost:
- The ability to continuously introduce innovative designs more quickly than competitors:
- Shorter lead times and more reliable delivery performance: and
- Customer service.

It is this holistic approach that has enabled some organisations to achieve market dominance over traditional manufacturers.

## 2.11 Current measures for manufacturing performance (MP)

In this paper, the researcher is measuring manufacturing performance at the plant level. The measures for overall financial measures of plant performance are not appropriate since the plant does not control sales or costs. The measures of manufacturing performance which are appropriate for this study are as follows:

- Cost: This is the economic cost associated with inventories as well manufacturing cost measured as a percentage of sales. A high inventory turnover ratio indicates a low cost position.
- On-time deliveries and speed of delivery performance are measures which are indicative of a plant's ability to deliver quickly and as promised.
- Quality: In this instance, conformance to quality is considered.
- Flexibility: This reflects an organisation's capability to make changes.

Use of these measurements can be traced to Schroeder (1993) and Ward et al. (1995). These authors support TPM's positive influence and its ability to enhance the technology base of the organisation which leads to improved Manufacturing Performance (MP). TPM can improve the technological base of an organisation by enhancing equipment technology and improving the skill of employees.

TPM, when part of a world-class manufacturing strategy that incorporates JIT (Just-In-Time) and TQM, should also lead to improved manufacturing performance. The relationship between JIT and TPM is clear. JIT's emphasis on waste reduction creates an environment where inventory is reduced, production processes are interdependent and the plant operation is less susceptible to breakdowns of the process.

TPM provides dependable equipment, reduces the number of production disturbances and increases plant capacity by providing effective equipment maintenance (Mcklone et al, 2001).

Todd (1995:44) summarises the key elements of JIT as:

- Exposing fundamental problems and putting them right, once and for all, so that they do not keep recurring (instead of holding extra stocks "just in case" things go wrong);

- Reducing manufacturing throughput times, effectively replacing traditional batch production with continuous processing through the use of cell manufacturing and set-up reduction techniques;
- Improving supplier performance to stop material problems interfering with the organisation's ability to satisfy its customers' requirements;
- Improving quality because shorter lead times and lower stocks mean that an organisation can no longer have protection against things going wrong; and
- Improving labour flexibility through cross-training so that the organisation is able to deal with the fluidity of customer demand.

Reducing lead times is one of the most important ways to improve competitive edge (Todd, 1995). From the above, it is clear that TPM indirectly influences manufacturing performance by supporting the JIT concept.

## 2.12 Benefits of TPM on manufacturing performance

The literature study reveals that TPM helps organise maintenance activities by applying the following actions (Tsang, 2002):

- It cultivates a sense of ownership in the operator by introducing autonomous maintenance, i.e. the operator takes responsibility for the primary care of his/her plant which results in improved safety and higher morale. The tasks include cleaning, routine inspection, lubrication, adjustments, minor repairs as well as the cleanliness of the local workspace.
- It develops cross-functional teams, consisting of operators, maintainers, engineers and managers which improve individual employee and equipment performances.
- It establishes an optimal schedule of clean-up and preventive maintenance which extends the plant's life-span and maximises its uptime.

Many TPM operators have achieved excellent progress (Lee, 2002), in instances such as:

- Wiser assessments of and improvements in the performance of critical equipment in terms of OEE and determining reasons for any non-achievement.
- Better understanding of the equipment's criticality and where and when it is financially worth improving.
- More cooperative teamwork, which results in less adversarial or competitive approaches between production and maintenance workers.
- Improved procedures for a) change-over and set-ups, b) carrying out maintenance tasks and c) better training of operators and maintenance employees: all lead to reduced unit costs of production and better service.
- Increased enthusiasm, loyalty and involvement of the workforce.

Rubrich and Watson (2000) also describe the results of total productive maintenance implementation as:

**Reduced variability** (of production parts and production schedules)
Variation in a manufacturing system comes in many different forms such as hardware variability, throughput variation and inventory variation. Reduced variation results from equipment that has greater accuracy and repeatability, and from less unexpected breakdowns.

According to Masaaki (1986), companies that have implemented TPM have seen “reductions in breakdowns of between 80 and 90 per cent and cost of defects drop by 55 per cent”. Robinson et al (1995) also says that “product lead times have been cut by 50 to 70 per cent, and on-time deliveries have been increased between 50 and 95 per cent. These levels of improvement document the large potential gains that some companies have achieved.

**Increased productivity**

Since the equipment is breaking down less frequently, the machines and operators are not waiting around while it gets repaired. Also, there is more throughput due to less total downtime, reduced set-up times, and fewer equipment adjustments, ie eliminating unscheduled downtime and excessive rework allows the organisation to spend more of its time on the value-added tasks such as producing good parts.

The documented gains from TPM include the value-add time per person growing by between 100 to 150 per cent and labour productivity increases of up to 150 per cent (Nakajima, 1989).

**Reduced maintenance costs**

The changing role of maintenance from breakdown repair to proactive improvement enables the organisation to reduce its overall maintenance costs. The traditional fire fighting approach to equipment maintenance forces organisations to carry extra staff members to handle the fluctuating and unpredictable workload. By using scheduled maintenance events, the organisation can level the load of work across all staff members.

The documented benefits from TPM in these instances include maintenance spending reduced by 40 per cent, energy conserved by 30 per cent and reduced maintenance labour by 60 per cent (Nakajima, 1989).

**Reduced inventory**

The manufacturing system does not need to store as much in-process inventory to cushion downstream processes against excessive equipment failures. Furthermore, the spare parts inventory can be reduced based on more accurate estimates of component replacement requirements.

From the above discussion, it can be shown that TPM forces fundamental rethinks of business processes to achieve lower unit costs, higher quality of end product and more rapid production.

## 2.13 Summary

In conclusion, this chapter has shown that TPM provides a comprehensive company-wide approach to maintenance management, which can be divided into long-term and short-term elements (Mcklone et al, 2001). In the long term, efforts focus on new equipment design and elimination of sources of lost equipment time and typically require the involvement of many areas of the organisation. In the short-term, TPM activities include an autonomous maintenance programme for the production department and a planned maintenance programme for the maintenance department. In this paper, the researcher focuses on the short-term efforts.

In this chapter, TPM approach has been shown to share many common features with Total Quality Management (TQM), Just-in-Time and lean manufacturing. TPM can be seen as the extension of the world-class manufacturing techniques or programmes.

The fundamental measure of TPM was also defined as the OEE value and the seven driving forces of TPM, which provide direction for improvement based activities within manufacturing organisations, were also discussed. Measures for manufacturing performance were also considered and it was shown that these support an organisation's internal rate of change as well as focus business improvements in line with commercial requirements.

Through the literature review, TPM has been identified as a strong contributor to the strength of the organisation and has the ability to improve manufacturing performance. World-class manufacturing techniques such as JIT, TQM and TPM are closely related and when combined, can increase manufacturing performance.

With competition in manufacturing industries rising relentlessly, TPM can be used as a philosophy to help prevent the failure of an organisation. Furthermore, TPM helps to improve the organisation's capabilities by enhancing the problem-solving skills of team members.

# CHAPTER 3

# RESEARCH DESIGN AND METHODOLOGY

## 3 Introduction

The purpose of this chapter is to explain the research design and methodology that has been followed to reach the conclusion of the research topic. The research process and the role of concepts and theory will also be discussed.

DCSA's Colt production facility in the Eastern Cape was selected for the study of the impact of Total Productive Maintenance on manufacturing performance.

## 3.1 Daimler Chrysler South Africa (DCSA)

The new Mercedes-Benz C-Class right hand drive and Mitsubishi Colt (L200) pickup are produced at DCSA's manufacturing plant in East London. The C-Class is exported into right hand drive markets worldwide and the Mitsubishi Colt into Africa only. With over 3 000 employees, the DCSA East London plant is one of the largest employers in South Africa's Border Kei region, maintaining its status as a major contributor to regional economic growth (http:www.daimlerchrylser.co.za).

After considering this information, the researcher selected one of DCSA's production facilities for the purpose of this study, namely the Colt production facility. This facility employs 228 employees and includes the bodyshop, assembly line, paintshop, and final finish.

## 3.2 Definition of research

Research is a process of planning, executing and investigating in order to find answers to our specific questions (Ghauri & Gronhaug, 2002:3). Leedy (1997:5) defines research as a process through which we attempt to achieve systematically and with the support of data the answer to a question, resolution of a problem, or a greater understanding of a phenomenon. The above serves to confirm that the researcher has to establish an appropriate

strategic choice of research design and this should come up with an approach that allows for answering the research problem in the best possible way – within the given constraints (Ghauri & Gronhaug, 2002:47).

## 3.3 Research design and problem structure

Ghauri and Gronhaug (2002), define research design as the overall plan for relating the conceptual research problem to relevant and practicable empirical research. Empirical research is conducted to answer or enlighten research questions.

On the other hand, Leedy (1997:93) defines research design as the visualisation of the data and the problems associated with the employment of those data in the entire research project as well as common sense and the clear thinking necessary of the management of the entire research endeavor – the complete strategy of attack on the central problem. With the stated definitions, one sees that problems may vary in structure, i.e. how well they are understood. Based on the problem structure, (Ghauri & Gronhaug, 2002:48) distinguish between the following types of research designs:

| ***Research design*** | ***Problem structure*** |
|---|---|
| Exploratory | Unstructured |
| Descriptive | Structured |

### 3.3.1 Exploratory research design

When the research problem is badly understood, that is, qualitative and unstructured, a (more or less) exploratory research design is adequate and a key characteristic of this approach is its flexibility, i.e. That is the ability to observe, get information, and construct explanation, i.e. theorising. This type of research rarely uses questionnaires, large samples and probability plans. Rather, the researcher is alert to new insights and ideas as he progresses with the research. The focus of the research may, thus, shift as new insights are discovered.

### 3.3.2 Descriptive research design

In this type of research, the problem is quantitative in nature, structured and well understood. The key characteristics of descriptive research are structure, precise rules and procedures. The assumption in this type of research is that relevant secondary is not available and the researcher plans to collect data by a survey using personal interviews. A detailed plan must be made with regard to how many and who to interview, ie sampling plan.

The researcher must also construct questions and make procedures on how the interviews should be conducted and questions reported. All interviews should be conducted the same way, ie the variation in the data collection should be as small as possible (Ghauri & Gronhaug, 2002).

## 3.4 Improving measurements

According to Ghauri & Gronhaug (2002:72), descriptive research as well as exploratory research measurements can be improved through the following:

- The researcher should start by elaborating the conceptual definitions and specifying the domain of constructs to be used. When dealing with practical problems, the point of departure should be the actual problem and how the problem can be represented or modeled,
- Adequate operational definitions (measures) should be developed. The researcher should inspect prior measurements used to capture the same constructs. In this phase, the face validity of the measurements should be assessed. Face validity tells us to what extent the measure used seems to be a reasonable measure for what it purports to measure. A simple test for face validity would be to ask for the opinion of others acquainted with the actual topic.
- Then the measures should then be corrected and refined.
- The measures should be pre-tested and their reliability and construct (convergent and discriminant) validity should be evaluated,
- Lastly, the final measurement instrument is used in the study.

From the above discussion, it follows that the questionnaire design is closely related to measurement.

## 3.5 Research Method

Ghauri & Gronhaug (2002:85) refer to research method as a systematic, focused and orderly collection of data for the purpose of obtaining information from them, to solve/answer research problems or questions. A range of data sources are available from **secondary** as well as **primary** research sources.

Dunsmuir and Williams (1992) illustrate the advantages and disadvantages of secondary research in Table 3.1.

**Table 3.1 Advantages and disadvantages of secondary research**

| Advantages | Disadvantages |
|---|---|
| ✓ Cheap and accessible – especially a university library<br>✓ Often the only resource, for example historical documents<br>✓ Only way to examine large-scale trends | ✓ Lack of consistency of perspective<br>✓ Biases and inaccuracies cannot be checked<br>✓ Published statistics often raise more questions than they answer<br>✓ The concern over whether *any* data can be totally separated from the context of its collection. |

*Source*: Dunsmuir and Williams (1992)

Dunsmuir and Williams (1992), state the most common primary research sources as:

- Social surveys
  - ✓ Questionnaire surveys
  - ✓ Interviews: Informal or structured

- Observation
  - ✓ Participant (overt) or covert (masked identity)

Advantages and disadvantages of primary research are shown in table 3.2.

**Table 3.2 Advantages and disadvantages of primary research**

| **Advantages** | **Disadvantages** |
|---|---|
| Quick and cheap if the sample is small:<br>• Computer coded for quick analysis and repetition<br>• Coding enables multiple comparisons among variables<br>• Allows generalisation to a larger population<br>• Verifiable by replication and requestioning of interviewees/respondents | Using a large sample can be time-consuming:<br>• Over-reliance on statistical analysis loses individual meanings and case study data,<br>• Closed questions may constrain the data (pre-empting a richer range of response)<br>• Respondents may interpret the questions differently<br>• Researchers can bias the data by concept definition and question framing<br>• It is impossible to check if people are responding honestly<br>• Response rate may be low and selection non-random. This affects the validity of any inferred generalisations. |

*Source*: Dunsmuir and Williams (1992)

At the outset, a researcher has to decide whether to use a qualitative or quantitative data collection and analysis method.

### 3.5.1 Qualitative versus quantitative research methods

The main difference between qualitative and quantitative research is not "quality" but procedure. In qualitative research, findings are not arrived at by statistical methods or other procedures of quantification. Reichardt & Cook (1979), as quoted by Ghauri & Gronhaug (2002:86), illustrate the main differences between qualitative and quantitative in Table 3.3.

**Table 3.3: The difference in emphasis in qualitative versus quantitative methods**

| Qualitative methods | Quantitative methods |
|---|---|
| • Emphasis on understanding | • Emphasis on testing & verification |
| • Focus on understanding from respondent's point of view. | • Focus on facts and/or reasons for social events |
| • Interpretation and rational approach | • Logical and critical approach |
| • Observations and measurements in natural settings | • Controlled measurements |
| • Subjective "insider view" and closeness to data | • Objective "outsider view" distant from data |
| • Explorative orientation | • Hypothetical-deductive; focus on hypothesis testing |
| • Process orientated | • Result oriented |
| • Holistic perspective | • Particularistic and analytical |
| • Generalisation by comparison of properties and contexts of individual organism | • Generalisation by population membership |

*Source*: Based on Reichardt and cook (1979)

### 3.5.2 Qualitative research methods

Qualitative research is collecting, analysing and interpreting data by observing what people do and say. Whereas, quantitative research refers to counts and measures of things, qualitative research refers to the meanings, concepts, definitions, characteristics, metaphors, symbols and descriptions of things.

Participants are asked to respond to general questions and the interviewer probes and explore their responses to identify and define people's perceptions, opinions and feelings about the topic or idea being discussed and to determine the degree of agreement that exists in the group.

This type of research method is often less costly than surveys and is extremely effective in acquiring information (http://uk.geocities.com).

### 3.5.3 Quantitative research methods

Quantitative research is research involving the use of structured questions where the response options have been predetermined and a large number of respondents are involved. By definition, measurement must be objective, quantitative and statistically valid. Simply put, it's about numbers, objective hard data.

Basically, quantitative research is objective and qualitative is subjective. The decision of whether to choose a quantitative or a qualitative research design is a philosophical question. In fact, elements of both designs can be used together in mixed-methods studies.

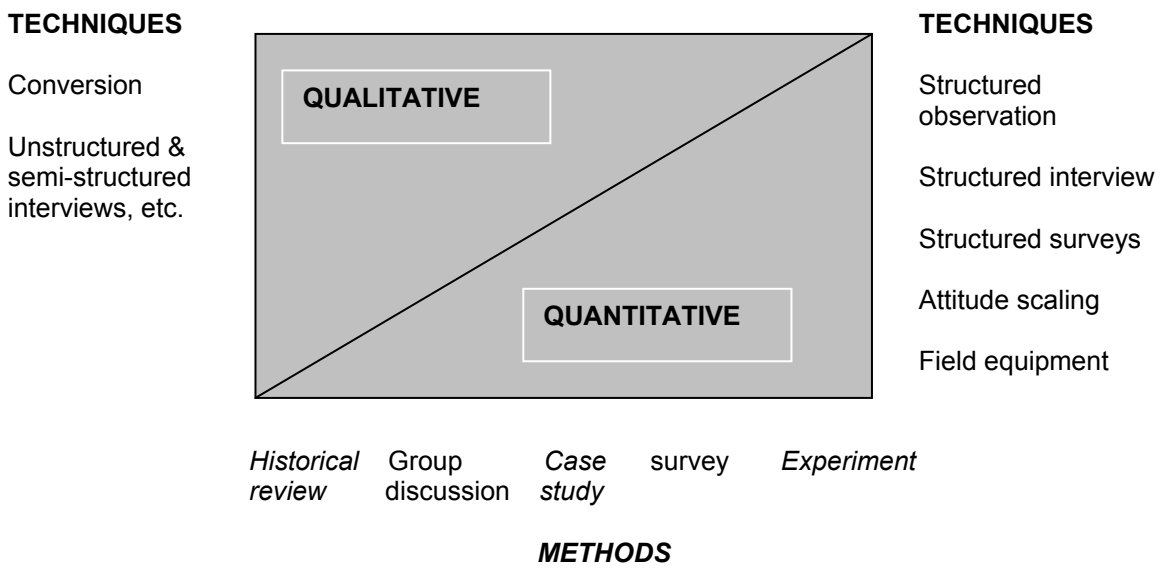
The advantages of using both types of research include:

- Research development (one approach is used to inform the other);
- Increased validity (confirmation of results by means of different data sources);

- Complementary (adding information, i.e. words to numbers and vice versa); and
- Creating new lines of thinking by the emergence of fresh perspectives and contradictions (http://uk.geocities.com).

Jankowicz (1991:159), as quoted by Ghauri & Gronhaug (2002:88), states that many scholars claim that the two approaches (quantitative and qualitative research) are complementary and cannot be used in isolation from each other. According to this view, no method is entirely qualitative or quantitative. However, the techniques can be either quantitative or qualitative. Figure 3.1 illustrates this point further.

**Figure 3.1: Quantitative and qualitative methods and techniques**




*Source*: Based on Jankowicz (1991:159)

From the figure, it can be seen that the methods, from left to right, become more quantitative and use more quantitative techniques. Historical review, group discussions and case studies are mostly qualitative research methods. These qualitative methods use relatively more qualitative techniques such as conversation and in-depth semi-structured interviews.

## 3.6 Research surveys and interviews

Ghauri & Gronhaug (2002:93) define surveys as a method of data collection that utilises questionnaires or interview techniques for recording the verbal behaviour of respondents. The survey is an effective tool to collecting opinions, attitudes and descriptions as well as for getting cause-and-effect relationships.

In research, two types of interviews are used. The first is survey research or structured interviews, where, according to Ghauri & Gronhaug (2002:100), a standard format of interview is used with an emphasis on fixed response categories and systematic sampling and loading procedures combined with quantitative measures and statistical methods. The second type is unstructured interviews, where a respondent is given almost full liberty to discuss reactions, opinions and behaviour on a particular issue.

## 3.7 Detail on the research design and methodology used at the Colt plant

The research design and methodology that has been followed is of a descriptive nature where the researcher decided to collect information /data through primary sources.

Data was collected from questionnaires sent out during August and September 2006, as well as through personal observations and interviews with people involved in Total Productive Maintenance within the Colt production facility. Secondary data were collected from literature research.

During the planning stages of the research, it was decided that a questionnaire would be developed and utilised at the Colt plant. This method was chosen on the basis of being cost-effective and convenient for respondents to complete. Before discussing the actual survey, the development of the questionnaire will be discussed.

### 3.7.1 Questionnaire design

The major issues were highlighted from the literature survey and considered for inclusion in the questionnaire. The questions were laid out in such a manner as to cover all aspects of TPM that had been identified as being important from the literature survey. The questions probed the respondents' understanding of Total Productive Maintenance.

The questionnaire (scaled and dichotomous questions) which was used in conducting the survey of all level employees at the Colt plant is as shown in **Annexure B**.

According to Ferreira (2005), a scaled question is one where the multiple choice alternatives provided give some idea of a progression in size or order of something. The researcher used the Likert scales which are used to get people's attitudes by asking them the extent of their agreement or disagreement with a series of statements about something. Dichotomous questions offer only two alternatives, for example, yes or no.

### 3.7.2 Pretesting the questionnaire

On completion of the questionnaire, five employees from the selected organisation were approached to complete and pretest the questionnaire.

Ferreira (2005), defines a pretest as the cheapest insurance that:

- The data collected will be as useful as possible to answering the problem.
- The target respondents will co-operate as fully as possible.
- The collection and analysis of data will proceed as smoothly as possible.

The reason for the pretest was to highlight any unclear questions. On receiving the questionnaire back from the above mentioned people, the

researcher made the necessary adjustments. The final questionnaire consisted of:

- *Section A* - 26 Likert Scale questions

  Likert scales are used to get people's attitudes by asking them the extent of their agreement or disagreement with a series of statements about an issue. They overcome the problem of semantic differential questions of having to find opposite adjectives. They use declarative statements (Ferreira, 2005).

  The researcher used the following five scale points range:

  5 - Strongly agree
  4 - Agree
  3 - Neutral (neither agree nor disagree)
  2 - Disagree
  1 - Strongly disagree

- *Section B* – 4 dichotomous questions
  Dichotomous questions are closed questions which offer only two alternatives, for example, yes or no, male or female, and agree or disagree.

  The researcher used the dichotomous questions because of the following advantages:

  - It is possible to answer quickly, with little effort, so they are well accepted by respondents as well as interviewers.
  - Tabulation and data reduction is simplified.
  - The alternative answers give an idea to the respondent as to what is expected.
  - The interviewer cannot introduce bias in the recording as it simply entails making a cross in the applicable block (Ferreira, 2005).

- *Section C* – Questions on demographic information
  The demographic information was analysed according to qualification, position or designation in the company and number of years spent on TPM activities.

**Sections A, B, C are illustrated in Annexure B.**

## 3.8 Research population

The plant under review consists of 228 employees. The sampling plan that was used depended on the team which was exposed to Total Productive maintenance (TPM) at the Colt production facility. The team consisted of about 75 employees. According to Ghauri & Gronhaug (2002), it is very important that the sample that is selected should faithfully represent the group to be studied. This does not mean that the sample has to be very large. As Cooper & Emory (1995:205) state "much folklore surrounds the question of sample size; one false belief is that the sample must be large or it is representative. This is much less true than most people believe".

The sampling technique ensured that the sample was representative and could be used to generalise about the population. As Leedy (1997) put it: "No matter how good the gathering of data is … the survey cannot be accurate if the people in the sample are improperly selected". The researcher decided that the full compliment of the whole TPM team would be approached to complete the questionnaire.

The sample size, as per positions, held in the company, was:

| | | |
|---|---|---|
| Departmental managers | - | 4 |
| Team managers | - | 9 |
| Artisans, operators and assistants | - | 61 |

In order to ensure a high response rate, a covering letter, as shown in **Annexure A**, was sent to each respondent, explaining why the research was

being carried out and the questions asked were being kept simple. The management of the selected plant was also offered the survey results.

### 3.9 The actual survey

After completing the questionnaire, an appointment with the respective managers was confirmed to discuss the planned survey. The objectives of the study were then discussed and it was decided that the researcher would be introduced to the respective team leaders and TPM facilitators. They then assisted the researcher to introduce the research project to the team members.

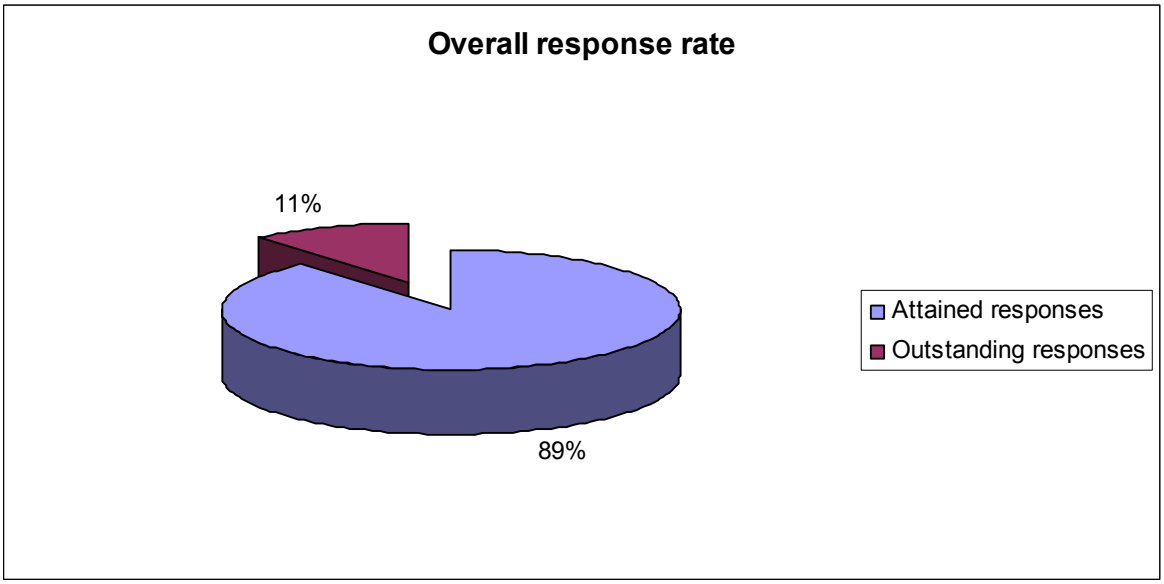
At the time of the survey, **70** questionnaires were sent out and **62** responses were received, giving an overall response of **89** per cent. The overall response rate is depicted in Table 3.4.

**Table 3.4: Overall response rate**

| RESPONSES | RESPONSE FREQUENCY | PERCENTAGE |
|---|---|---|
| Attained responses | 62 | 89% |
| Outstanding responses | 8 | 11% |
| TOTAL | 85 | 100% |

*Source*: **Results from the survey**

**Pie chart 3.1**




*Source:* **Table 3.4 – Converted to a Pie Chart**

According to Saunders et al. (2000, p.259), "a response rate of 80 per cent can be achieved, if the respondent's co-operation is secured, and if the idea can be put over that the survey is of importance to him/her personally, and if the questionnaire is short, and simple".

After the survey, the researcher asked team members what their opinion was with regards to questionnaires and a positive response was received, with the common statement being that questionnaires assist management in solving the concerns of the employees.

## 3.10 Interviews at the Colt plant

The researcher visited the Colt production facility and interviews were conducted with the production and maintenance personnel as well as with managers of production and maintenance. The questions asked concerned all the various strategies that the Colt plant introduced to improve productivity

and competitiveness. The plant visits also allowed the researcher to observe the use of Total Productive Maintenance (TPM) information on the shop floor.

## 3.11 Summary

In this chapter the research design and methodology for the study of the impact of total productive maintenance at the Colt production facility on manufacturing performance is explained. A literature survey was also undertaken to look into the research process and the questionnaire design. It was also noted that questionnaires were sent out to a sample of selected employees across all levels of the plant. The research designs – exploratory, descriptive and causal - were also presented in order for the researcher to choose between qualitative or quantitative research methods. The empirical study, which is the information from data collection, will be presented in Chapter 4.

# CHAPTER 4

# RESEARCH FINDINGS

## 4 Introduction

The main aim of this chapter is to present the empirical findings of the impact of Total Productive Maintenance (TPM) on manufacturing performance at DCSA's Colt production facility in the Eastern Cape. The questionnaire was sent to 70 employees at the Colt production facility. The sample population consisted of:

- Departmental managers;
- Team managers; and
- Line supervisors, artisans and machine operators.

The findings are presented in table 4.1 and the questionnaires (Annexure B) as well as the interviews concerning TPM are explained. The interviews were done with a view to establishing how TPM has impacted on manufacturing performance. The questionnaire covers the elements of Total Productive Maintenance (TPM) as discussed in Chapter 2.

## 4.1 Results of the questionnaire and interviews

The questionnaire was constructed to measure the elements of Total Productive Maintenance as well as manufacturing performance goals as described in Chapter 2. The interviews were all centred on the research survey as well as various initiatives which are related to TPM within the production facility.

According to senior management at the Colt production facility, quality is a core driver and intrinsic to DCSA's business. The introduction of the DaimlerChrysler Operating Model (DCOM) assisted its production process since it introduced TPM which is structured and systematic. The DCOM is a carefully structured model of how production processes are designed,

implemented and sustained in an effort to yield world-class results (http:www.daimlerchrylser.co.za).

The model subscribes to a zero-defect target, whereby faults are best avoided or eliminated immediately. DCOM is the first intervention strategy that the Colt Production facility implemented to improve productivity and competitiveness and it is an initiative that had culminated in the implementation of Total Productive Maintenance (TPM).

The following sections analyses the Colt production facility - its intent is to analyse the TPM activities and not to completely evaluate all aspects of each manufacturing system.

### 4.1.1 Results from Section A – Measurement of TPM

Table 4.1 shows the responses from the research questionnaire in Annexure B. From the table, the first column shows the questions from Annexure B, the second column shows number of people (**No**) and percentage (**%**) of the total number of people and the third column shows the Likert scale - the numbers represent the following:

| | | |
|---|---|---|
| 5 | - | Strongly agree |
| 4 | - | Agree |
| 3 | - | Neutral (neither agree nor disagree) |
| 2 | - | Disagree |
| 1 | - | Strongly disagree. |

**Table 4.1: Responses from the research questionnaire**

| Questions | No | Likert Scale | | | | |
|---|---|---|---|---|---|---|
| | % | 5 | 4 | 3 | 2 | 1 |
| 1.Total Productive Maintenance (TPM) principles are currently applied at your organisation. | No | 17 | 42 | 2 | 1 | 0 |
| | % | 27 | 68 | 3 | 2 | 0 |
| 2. Through TPM, the need for preventive maintenance at your company is determined for every machine. | No | 10 | 45 | 5 | 2 | 0 |
| | % | 16 | 73 | 8 | 3 | 0 |
| 3. At your company, TPM improves planned maintenance systems. | No | 11 | 44 | 3 | 4 | 0 |
| | % | 18 | 71 | 5 | 6 | 0 |
| 4. TPM improves the quality of maintenance and hence productivity. | No | 14 | 35 | 9 | 4 | 0 |
| | % | 23 | 56 | 15 | 6 | 0 |
| 5. TPM addresses cleanliness and workplace organisation, eliminating dust, dirt and disarray. | No | 7 | 25 | 21 | 9 | 0 |
| | % | 11 | 40 | 34 | 15 | 0 |
| 6. Production operators at your company have accepted that autonomous maintenance is their responsibility. | No | 7 | 30 | 13 | 11 | 1 |
| | % | 11 | 48 | 21 | 18 | 2 |
| 7. Shop floor workers are organised in TPM teams for problem solving and the team objectives are aligned with departmental objectives. | No | 1 | 25 | 19 | 17 | 0 |
| | % | 2 | 40 | 31 | 27 | 0 |
| 8. All the TPM teams are empowered to take responsibility for their decisions. | No | 1 | 30 | 10 | 21 | 0 |
| | % | 2 | 48 | 16 | 34 | 0 |
| 9. TPM unlocks the potential of the workforce through an increase in skills and knowledge. | No | 8 | 35 | 11 | 8 | 0 |
| | % | 13 | 56 | 18 | 13 | 0 |
| 10. With TPM, workers are routinely involved in some organised form of continuous improvement activity (Kaizen). | No | 6 | 30 | 20 | 6 | 0 |
| | % | 10 | 48 | 32 | 10 | 0 |
| 11. At your company, the maintenance department focuses on assisting production operators for TPM activities. | No | 8 | 33 | 12 | 9 | 0 |
| | % | 13 | 53 | 19 | 15 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12. Total Productive Maintenance improves teamwork between production and maintenance departments. | **No** | 8 | 41 | 9 | 3 | 1 |
| | **%** | 13 | 65 | 15 | 5 | 2 |
| 13. Top management strongly encourages employee involvement on TPM activities at your company. | **No** | 9 | 30 | 15 | 8 | 0 |
| | **%** | 15 | 48 | 24 | 13 | 0 |
| 14. Total Productive Maintenance improves equipment availability at your company. | **No** | 12 | 44 | 3 | 3 | 0 |
| | **%** | 19 | 71 | 5 | 5 | 0 |
| 15. Total Productive Maintenance improves equipment reliability so as to improve or replace machinery elements which are not robust and reliable. | **No** | 10 | 41 | 7 | 4 | 0 |
| | **%** | 16 | 66 | 11 | 6 | 0 |
| 16. Through TPM, machine speed losses are continuously detected at your company. | **No** | 7 | 37 | 11 | 7 | 0 |
| | **%** | 11 | 60 | 18 | 11 | 0 |
| 17. Total Productive Maintenance at your company strives for zero breakdowns. | **No** | 11 | 43 | 5 | 3 | 0 |
| | **%** | 18 | 69 | 8 | 5 | 0 |
| 18. TPM improves manufacturing performance through chronic loss analysis. | **No** | 4 | 42 | 10 | 6 | 0 |
| | **%** | 6 | 68 | 16 | 10 | 0 |
| 19. TPM, at you company, also focuses on health, safety and environmental issues. | **No** | 8 | 38 | 11 | 5 | 0 |
| | **%** | 13 | 61 | 18 | 8 | 0 |
| 20. TPM ensures that plant and equipment are used to their maximum effectiveness. | **No** | 9 | 48 | 2 | 3 | 0 |
| | **%** | 15 | 77 | 3 | 5 | 0 |
| 21. At your company, charts plotting the frequency of machine breakdowns are posted on the shop floor. | **No** | 9 | 25 | 15 | 13 | 0 |
| | **%** | 15 | 40 | 24 | 21 | 0 |
| 22. TPM provides visibility to all major losses that are a result of poor equipment performance. | **No** | 6 | 42 | 12 | 2 | 0 |
| | **%** | 10 | 68 | 19 | 3 | 0 |
| 23. At your company, TPM reduces maintenance costs. | **No** | 8 | 35 | 13 | 5 | 1 |
| | **%** | 13 | 56 | 21 | 8 | 2 |
| 24. TPM works to reduce process defects at your company. | **No** | 8 | 36 | 11 | 6 | 1 |
| | **%** | 13 | 58 | 17 | 10 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 25. At your company, Total Productive Maintenance is implemented by various departments (engineering, operations, and maintenance). | **No** | 6 | 30 | 15 | 11 | 0 |
| | **%** | 10 | 48 | 24 | 18 | 0 |
| 26. At your company, Total Productive Maintenance involves every single employee, from top management to workers on the shop floor. | **No** | 5 | 21 | 19 | 16 | 1 |
| | **%** | 8 | 34 | 31 | 25 | 2 |

Source**: Survey questionnaire, Section A.**

Table 4.1 (Questions 1-26) reveals the following about the respondents:

**Question 1:** 27 per cent strongly agreed and 68 per cent agreed while neutral and the "disagreed" respondents equalled five per cent. This result is positive and shows that 95 per cent of respondents attest that TPM principles are currently applied at the Colt plant. Senior management supported the implementation of TPM which had resulted in improved availability, reliability, quality and elimination of waste.

**Question 2:** 16 per cent strongly agreed and 73 per cent agreed that through TPM the need for preventive maintenance at the Colt plant is determined for very machine. This is an excellent result since preventive maintenance is a concept which adds value to manufacturing performance through TPM. According to Nakajima (1988), preventive maintenance is a function which consists of periodic inspections, planned restoration of deterioration and proactive replacement of suspect equipment components. While performing preventive maintenance, data should be collected for equipment effectiveness measurements, reliability studies, maintainability metrics and operating costs. Although this function is done at the Colt production facility, respondents felt that there is still room for improvement as far as TPM measurements are concerned.

**Question 3** reveals that 18 per cent strongly agreed and 71 per cent agreed that TPM improved their planned maintenance systems. On

interviewing the respondents, the researcher found that the planned maintenance systems covered the main areas such as timeous planned maintenance schedules, workloads that were efficiently planned and useful reports that were been produced. According to management, these practices have improved Colt plant's manufacturing performance.

**Question 4** reveals that TPM improved the quality of maintenance and hence productivity - 23 per cent strongly agreed and 56 per cent agreed, giving a total of 79 per cent. The other 21 per cent was represented by respondents who were neutral as well as ones who disagreed. The positive response (79%) showed that this element of TPM was crucial since interviewed respondents believed that quality maintenance aimed to delight customers. This resulted in defect free manufacturing and improved manufacturing performance. This element of TPM is fully covered in Chapter 2.

**Question 5** dealt with another element of TPM and the 5S method. It involved cleanliness and workplace organisation which eliminates dust, dirt and disarray. In this instance, 11 per cent strongly agreed while 40 per cent agreed giving a total "positive" percentage of 51 per cent. A total of 49 per cent representing the neutral and the disagreed. The benefits of this element of TPM include machine efficiencies and hence productivity (Chapter 2). On interviewing the respondents, the researcher found out that there was a lack of seriousness when it came to cleanliness and most of them said that they were not trained in the 5S method.

**Question 6** reveals that 59 per cent strongly agreed and agreed while 41 per cent represented a combination of neutral, disagree and strongly disagree. The result of this survey question revealed that there was still room for improvement. On observing and interviewing the respondents regarding autonomous maintenance, the researcher discovered that some TPM action tags were not being filled up or updated. This element of TPM, as described in Chapter 2, is of utmost importance in that it creates a

system of regular preventative maintenance cycles by the team which supports the conversion process by cleaning, lubricating and inspecting the assets under the control of the team in a pre-defined and timely manner. This element also improves manufacturing performance.

**Question 7** reveals that 2 per cent strongly agreed and 40 per cent agreed while 31 per cent and 27 per cent are neutral and disagree. During interviews, the respondents revealed that they did act as teams but there team synergy could be improved. Chapter 2 shows that one of the benefits of TPM teams that organisations recognise is increased productivity through improved machine efficiency, improvements in up-time and improved preventive maintenance. From the above statement, it can be shown that TPM impacts on manufacturing performance.

**Question 8** shows that 50 per cent strongly agreed and agreed while 50 per cent were neutral and disagreed that all TPM teams are empowered to take responsibility. Respondents felt there was room for improvement and that they should be given the necessary training, tools and data to effectively take ownership of their equipment and machines.

**Question 9** reveals that 13 per cent strongly agreed and 56 agreed that TPM unlocks the potential of the workforce through increased skills and knowledge while 18 per cent were neutral and 13 per cent disagreed. From the above, it can be seen that 69 per cent were in favour of TPM since they believed it increased in knowledge and skills. In interviews, the respondents said that this was a vital component of TPM because TPM's implementation had resulted in improved skills since many were now multi-skilled.

**Question 10** reveals that 10 per cent strongly agreed and 48 per cent agreed to another important element of TPM (Chapter 2), which is Kaizen. Thirty two per cent represented neutral views while 10 per cent disagreed. From the above, 58 per cent supported some form of continuous

improvement in the organisation while the 42 per cent disagreed and were neutral. During interviews, some respondents echoed the sentiment that in order to remain competitive, continuous improvement had to be entrenched with the philosophy of “if you can’t measure, you can’t improve”. Some of the respondents spoke of the Overall Equipment Effectiveness (OEE) measurement. To them, this measured quality, performance and equipment availability. Some respondents complained that the OEE system of some stations was not the real OEE and that in some instances OEE graphs were not being updated. They said that the existing data collection methods did not emphasise the benefits that could be achieved by accurately monitoring equipment performance.

**Question 11** reveals that 13 per cent strongly agreed and 53 per cent agreed while 19 per cent and 15 per cent were neutral and disagreed with statement describes the maintenance department as focusing on assisting production operators for TPM activities. During interviews, the respondents believed that the maintenance department had to improve in assisting the production operators. They believed that, in some instances, the maintenance department was secretive.

**Question 12** reveals that 13 per cent strongly agreed and 65 per cent agreed while 15 per cent were neutral, 5 per cent disagreed and 2 per cent disagreed that TPM improved teamwork between production and maintenance. The total (78%) of “strongly agreed” and “agreed” is good result and reflects a strong belief that TPM improved teamwork and therefore manufacturing performance.

**Question 13** reveals 15 per cent strongly agreed and 48 per cent agreed while 24 per cent and 13 per cent were neutral and disagreed. During interviews, the respondents who were neutral and disagreeing felt the greatest challenge to the success of TPM was a lack of direction from top management.

**Question 14** reveals that the respondents were in favour of TPM and that TPM improved equipment availability and hence manufacturing performance. 19 per cent strongly agreed and 71 per cent agreed while 5 per cent were neutral and 5 percent were disagreed.

**Question 15** reflects a positive attitude to TPM and improving equipment reliability. 16 per cent strongly agreed and 66 per cent agreed while 11 percent were neutral and 6 per cent disagreed. Chapter 2 attests to the fact that TPM implementation results in the improvement in equipment reliability and cost maintenance with the concomitant increase in manufacturing performance.

**Question 16** reveals that 11 per cent strongly agreed and 60 per cent agreed while 18 percent were neutral and 11 percent disagreed. During interviews, some respondents believed that TPM helped the continous detection of machine speed losses at the Colt plant although some felt that for them to be able to detect problems on their machines there is a need for more training.

**Question 17** reveals that 18 per cent strongly agreed and 69 per cent agreed. Only a few respondents (8% neutral, 5% disagree) were against TPM's aim of zero breakdowns. This was a positive response since respondents said that their manufacturing performance had increased because of the reduced cycle times.

**Question 18** reveals that 68 per cent agreed, 6 per cent strongly agreed, 16 per cent were neutral and 10 per cent disagreed. Respondents believed that TPM improved the effectiveness of machinery and equipment which directly affected key business ratios and competitiveness.

**Question 19** shows that 61 per cent agreed and 13 per cent strongly agreed while 18 per cent were neutral and 8 per cent disagreed. Respondents agreed that TPM has improved safety. Operators were

familiar with their machines and equipment due to daily inspections and minor maintenance performed. According to literature review, the above supports the belief that safety, health and environment were an important element of TPM.

**Question 20** reveals that 77 per cent agreed and 15 per cent strongly agreed. During interviews, respondents felt that TPM had improved the use the effectiveness of their machines and equipment.

**Question 21** reveals that 40 per cent agreed, 15 per cent strongly agreed, 24 per cent were neutral and 21 per cent disagreed. The respondents felt that management needed to improve as far as visual management aids are concerned. Charts needed to be updated constantly and posted at the right time on the shop floor.

**Question 22** reveals a positive response in that 68 per cent agreed and 10 per cent strongly agreed. The 19 per cent who were neutral felt that a lot needed to be done by the maintenance department in order to share the necessary knowledge with the production department.

**Question 23** shows that 56 per cent agreed and 13 per cent strongly agreed that TPM reduced maintenance costs. Respondents believed that with TPM, the role of maintenance from breakdown repair to proactive improvement had enabled their organisation to reduce its overall maintenance costs. Unnecessary replacement of components had also being reduced.

**Question 24** reveals that 58 per cent agreed, 13 per cent strongly agreed, 17 per cent were neutral and 10 per cent disagreed. During interviews, some respondents agreed that TPM reduced process defects but felt that training left a lot to be desired.

**Question 25** reveals that 48 per cent agreed, 10 per cent strongly agreed, 24 per cent were neutral and 18 per cent disagreed. According to Nakajima (1988), Total Productive Maintenance (TPM) was productive maintenance carried out by all employees through small group activities. Respondents felt that a lot needed to be done to reinforce that TPM impacted on the internal efficiency of the organisation.

**Question 26** reveals that 34 per cent agreed, 8 per cent strongly agreed, 31 per cent neutral. 25 per cent disagreed and two per cent strongly disagreed. Respondents felt that management was no longer supportive as they were during the early stages of TPM implementation. The management activities should include allowing production operators to attend training sessions on TPM and should be communicating the TPM goals to the entire Colt production facility. In essence, management should be the driving force behind the success of TPM.

### 4.1.2 Results from Section B – Manufacturing performance

Equipment efficiency is a commonly used metric for evaluating manufacturing performance. The efficiency, according to Nakajima (1988), is maximized by running the equipment at its highest speed, for as long as possible, to increase product throughput.

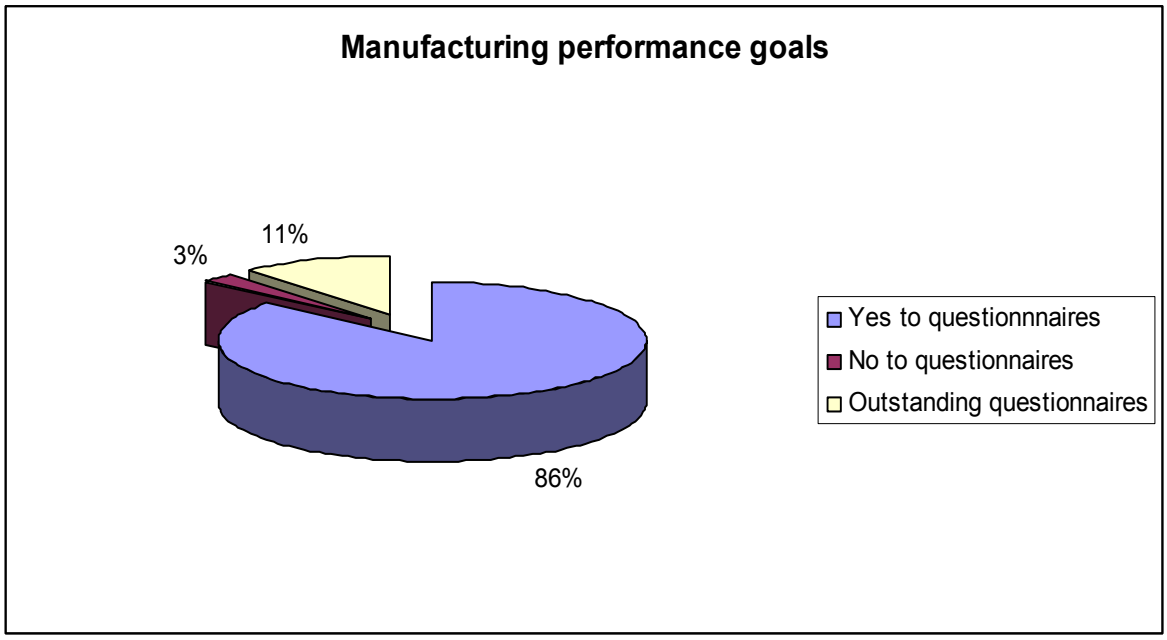
According to table 4.2, 86 per cent of respondents supported the specific numeric targets, as set by their organisation, in terms of manufacturing performance. During interviews, respondents felt that a lot needs to be done in using Overall Equipment Effectiveness (OEE) as a measure of manufacturing performance.

**Table 4.2: Manufacturing performance goals**

| SECTION B RESPONSES | RESPONSE FREQUENCY | PERCENTAGE |
|---|---|---|
| Yes to questionnaire | 60 | 86% |
| No to questionnaire | 2 | 3% |
| Outstanding responses | 8 | 11% |
| TOTAL | 70 | 100% |

*Source*: **Results from the survey, Section B**

**Pie chart 4.1**




*Source:* **Table 4.2 – Converted to a pie chart**

### 4.1.3 Results from Section C: Demographic information

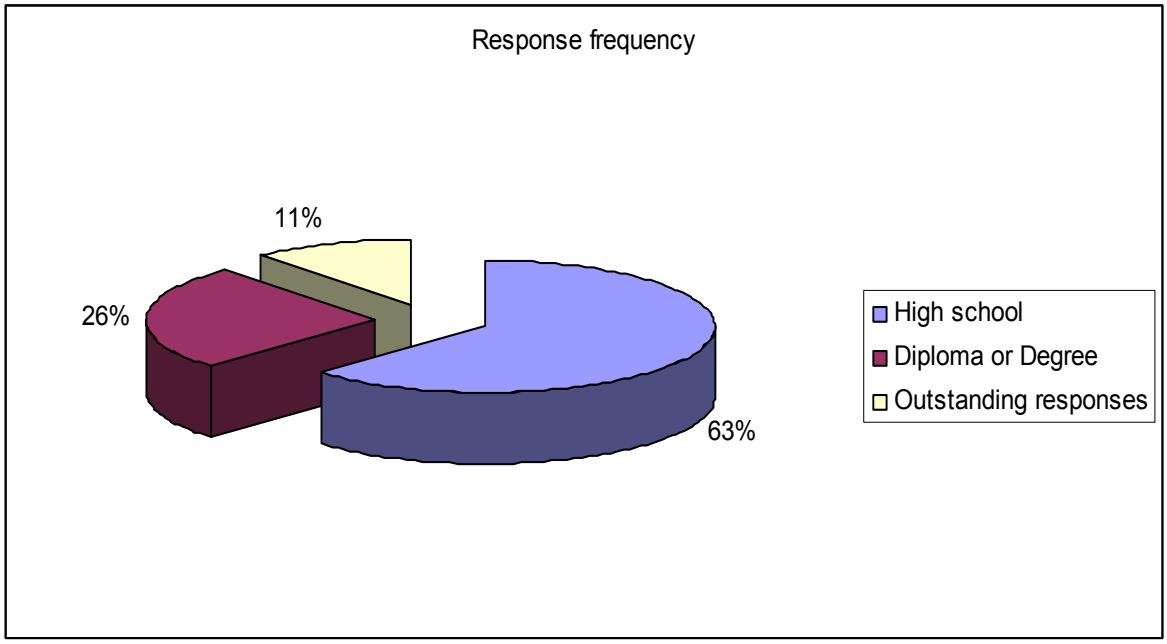
The table below shows the response to the survey by highest qualification.

**Table 4.3: Responses by highest qualification**

| HIGHEST QUALIFICATION | NUMBER OF RESPONSES | PERCENTAGE OF RESPONDENTS |
|---|---|---|
| High school | 44 | 63% |
| Diploma or Degree | 18 | 26% |
| Outstanding | 8 | 11% |
| TOTAL | 70 | 100% |

*Source*: **Results from the survey: Section C**

**Pie Chart 4.2**




*Source:* **Table 4.3 – Converted to a pie chart**

Table 4.3 shows that 63 per cent of respondents completed high school and 26 per cent of respondents completed a bachelor's degree or diploma. This is an indication that the majority of the respondents have some form of education and therefore it was easy for them to understand the implementation of TPM at their production facility as well as the research survey questionnaire.

The research survey also reveals that more than 75 per cent of employees had been involved in TPM in the past three years. The above indicates that TPM is practiced at the Colt production facility.

## 4.2 Summary

In this chapter, the researcher presented and analysed the research questionnaire (Annexure B). The view points from the interviews were also presented in order to explain what the respondents believed TPM's impact was on manufacturing performance. The results of the research questionnaire were also aligned to the literature review in Chapter 2.

In the next chapter, the researcher will present the summary of the research findings and conclusions which are based on the empirical survey. Recommendations and additional research opportunities will also be presented in the final chapter.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5 Introduction

This chapter provides a brief summary of the results of the research conducted at the Colt production facility. The conclusions drawn are based on the empirical survey. The problems experienced as well as the limitations will also be highlighted. Suggestions for further research opportunities, which may lead to a deeper understanding of Total Productive Maintenance (TPM), will also be discussed.

## 5.1 Summary of research

In consideration of the research questions from Chapter 1, this research paper has shown:

- The literature study indicates that TPM is a strong contributor to an organisation's competitiveness as well as manufacturing performance. In essence, the main aim of TPM is to increase productivity of plant and equipment so that it experiences maximum productivity. In addition to the above, TPM increases the availability of equipment and this allows organisations to defer the purchase of additional equipment to satisfy increases in production demand.

- Through the research, it has been shown that the Colt production facility is involved in TPM activities and has done a good job of getting some TPM activities deployed across their facility. However, there is room for improvement in some components of TPM, such as education and training and long-term management commitment which is critical to the success of TPM implementation.

- At the Colt plant, maintenance costs have been significantly reduced because maintenance activities are proactive rather than reactive.

Overall, this research paper indicates that the Colt production facility needs to improve its TPM programme which should result in further improvements in manufacturing performance.

## 5.2 Conclusions from research

The following specific conclusions have been complied from interviews and surveys administered during the research process as well as personal observations:

- The majority of respondents agree that TPM principles are being adhered to at the Colt production facility. From interviews, it was clear that the plant has improved with the implementation of TPM. TPM has had an impact on the availability, reliability, quality and performance of equipment and machinery.

- The majority of respondents agree that the Colt production facility has preventative maintenance schedules as part of TPM activity and are positive that TPM will help their plant to survive into the future.

- A number of respondents indicated that the implementation of an element of TPM, termed the 5S method, leaves a lot to be desired and is reflected in the lack of training. One of the challenges most evident for this production facility is the loss of people that have been involved in the TPM activities.

- A number of respondents also indicated that training is required to make autonomous maintenance effective. Visual control is also part of this TPM element where equipment is marked and labelled to make identification of conditions easier to identify. In some instances, the daily equipment checklists were not filled out.

- Most of the production operators and production team managers still view TPM as a maintenance issue, rather than as a production issue. This is a result of TPM issues being pushed to the maintenance department rather than the pooling of resources from both departments in order to achieve success.

- A number of respondents also indicated that there was a need for a clear strategic direction, support and understanding from top management concerning TPM. The lack of management support is attributed to management not completely understanding the true goal of TPM activities.

- Many of the respondents indicated that there is a lack of useful data to the lower levels of the production facility. The use of the Overall Equipment Effectiveness (OEE) data needs to improve. Furthermore, available data is not effectively utilised.

## 5.3 Recommendations from the research

The Colt production facility has, to an extent, made varying degrees of improvement with some TPM elements. The following indicates areas were there is room for improvement:

- Support and commitment from top management for TPM activities - Establishing a top management steering group would assist in:
  - Providing the necessary planning, commitment, direction and continuance of TPM activities.
  - Create and establish clear measures of performance including achievable milestones and objectives, using project management techniques (Bamber, 1998).
  - Incentives and rewards need to be revisited in order to encourage continuance of TPM activities. The goals of production and maintenance departments need to be linked so

that they work together in order to achieve the organisation's goals.

- Financial support for TPM activities – more manpower and intensive training. Management needs to train and develop a network of TPM facilitators that will promote and support TPM activities everyday. Roy Davis, a UK director of Manufacturing Productivity Improvements Ltd, considers a good awareness, education and training strategic plan to be an essential factor in the success of TPM (Davis, 1997).

  Training and education supports all the other TPM elements by ensuring that all employees have the necessary knowledge and skill to do a quality job while performing TPM activities. Employees include management, maintenance and production personnel. Training would provide employees with a deep understanding of TPM activities and the goals for manufacturing success.

- Alignment of management initiatives and organisational changes. Management should identify the required changes and any refinements affecting the current and future roles of their personnel. The appropriate training needs should be addressed so as to improve manufacturing performance.

- Cultural change for maintenance and production departments to take on plant care. The production department and maintenance department personnel should be measured on equipment performance and quality or cycle times as this would improve overall manufacturing performance. These departments have to be encouraged to maximise Overall Equipment Effectiveness.

- Give more autonomy and responsibility to production operators. Training on autonomous maintenance should benefit the production

department because the maintenance department would train the operators on how to properly clean and lubricate the equipment. This would create a visual factory environment through the 5S method.

- Greater communication between operations and maintenance departments. The Colt production facility should put in place relevant measures of performance and continually monitor and publicise benefits achieved in financial terms. The production facility also needs to develop simple data collection methods to gather information that can be effectively used by the operators in order to increase productivity and hence manufacturing performance.

- Regular review audits to address the elements of the entire TPM system should also provide a solid basis to improve manufacturing performance. According to Rich (1999), the ultimate goal of the audit process is to eliminate waste from the TPM support structure and provide meaningful management information, relating to the alignment of the policies and practices of TPM. In this manner, the TPM direction is truly aligned with the profit-oriented goals of the production facility.

## 5.4 Opportunities for further research

This research paper has provided insight into the impact of TPM on manufacturing performance. However, this research paper has created a lot of opportunities for further research. The following further research is recommended:

- **Aligning TPM and Total Quality Management (TQM) for productivity improvements:**

  Many organisations may benefit by aligning these two world-class manufacturing techniques through improved productivity and competitiveness. Employees could be encouraged to initiate their continuous improvement projects as well as elimination of

manufacturing waste. Improved quality, availability and reliability of equipment and machinery may also be experienced.

- **The impact of world-class manufacturing techniques on manufacturing performance:**
  A study could be conducted where all the world-class manufacturing techniques are identified and aligned to assess their contribution to manufacturing performance.

- **Analysing a TPM implementation project:**
  The lessons learned may provide insight into organisational changes that result from implementing TPM.

- **Assessing the benefits of TPM:**
  Many organisations may benefit from assessing the benefits of TPM. The lessons learned may be a strong driving factor for top management to implement TPM.

## 5.5 Summary

From the above, it was established that the Colt production facility was involved in TPM activities although there was room for improvement in training and provision of resources. Top management support was also crucial for the success of TPM as well as buy-in from the production and maintenance departments. There is also an indication that TPM has had a strong positive impact on manufacturing performance. Rich (1999) states that, the TPM rationale is simple: To create a profit and generate an income stream from the manufacturing process. He also indicates that TPM is mandatory for all manufacturing companies and is a means of taking practical steps towards perfect production performance. It is not a luxury best practice but a foundation on which the costs of the conversion process can be lowered continuously.

Recommendations based on the research findings were made and finally, opportunities for further research were outlined.

**List of References**

Bamber, C.J., Sharp, J.M. & Hides, M.T.1999. Factors affecting successful implementation of total productive maintenance. Journal of Quality in Maintenance Engineering 5(3), 162-181.

Bamber, C. 1998. Factors affecting successful implementation of total productive maintenance. MSc Research Dissertation, University of Salford.

Beach, R., Muhlemann, A.P., & Price, D.H.R. 2000. "Manufacturing operations and strategic flexibility: survey and cases." International Journal of Operations & Production Management 20(1), 7-30.

Campbell, J.D. and Jardine, A.K.S. 2001. Maintenance Excellence: optimising equipment life-cycle decisions. Marshal Dekker, New York.

Castka, P., Bamber, C., Sharp, J. and Belohoubek, P. 2001. Factors affecting successful implementation of high performance teams. Team Performance Management: An International Journal, Vol. 7, pp.123-34.

Churchill, G.A. 1999. Marketing Research: Methodological Foundations (6th ed.). Fort Worth. Dryden Press.

Dal, B., Tugwell, P. and Great banks, R. 2000. Overall equipment effectiveness as a measure of operational improvement, a practical analysis. International Journal of Operations & production Management, Vol. 20 No. 12, pp. 1488-502.

Davis, R.K. 1995. Productivity improvements through TPM. Prentice Hall.

Davis, R. & Willmott, P. (Eds.) 1999. Total Productive Maintenance. Asset maintenance management. Oxford: Alden Press.

Dunsmuir, A. and L. Williams. 1992. How to Do Social Research. Sociology in Action series. London: Collins Educational.

Ferreira, R. 2005. Research Methodology IV - Study guide. Faculty of Business and Economic Sciences, NMMU.

Ghauri, P. & Gronhaug, K. 2002. Research methods in business studies: A practical guide. Prentice Hall.

Hamacher, E.C. 1996. A methodology for implementing Total Productivity Maintenance in the Commercial Aircraft Industry. Thesis. Massachutes Institute of Technology.

Hartman, E.H. 1992. Successfully Installing TPM in a Non-Japanese Plant: Total Productive Maintenance. TPM Press Inc, London.

Imai, M. 1986. Kaizen: The key to Japan's Competitive Success. McGraw Hill, New York.

Jackson, M. 2000. An Analysis of flexible and Reconfigurable Production Systems. Doctoral thesis. Production Systems. Linkopings Universitet. Linkoping, Sweden.

Jankowicz, A.D. 1991. Business Research Projects for Students. London: Chapman and Hall.

Jeong, K. and Philips, D. 2001. Operational efficiency and effectiveness measurement. International Journal of Operations and Production Management.

Kotze, D. 1993. Consistency, accuracy lead to maximum OEE benefits. TPM Newsletter, Vol. 4 No. 2.

Leedy, P.D. 1997. Practical Research – Planning and design. Macmillan, New York, NY.

Lee, K. 2002. Total Productive Maintenance (TPM). http://www.maint2k.com

Liker, J.K. 2004. The Toyota Way. Madison: McGraw-Hill.

Maggard, B.N. and Rhyne, D.M. 1992. Total Productive Maintenance: a timely integration of production and maintenance. Production and Inventory Management Journal, 4th quarter, pp.6-10.

Malhotra N. 2002. Marketing Research: An Applied Orientation. 4th ed. Prentice Hall.

Mcklone, K.E., Schroeder, R.G., and Cua, K.O.2001. The Impact of Total Productive Maintenance Practices on Manufacturing performance. Journal of Operations Management, Vol.19, pp. 39-58.

Moubray, J. 2000. http://www.maintenanceresources.com

Nakajima, S. 1988. Introduction to TPM: Total Productive Maintenance. Cambridge, Productivity Press.

Nakajima, S. 1989. TPM Development Program. Cambridge, Productivity Press.
Prickett, P.W. 1999. An integrated approach to autonomous maintenance management. Integrated Manufacturing Systems, Vol. 10, No 4.

Rich, N. 1999. Total Productive Maintenance: The Lean Approach. Tudor Business Publishing.

Rich, N. 1997. The anatomy of Japanese maintenance Performance. Lean Enterprise Research Centre. Working paper series Cardiff Business School.

Robinson, C.J. and Andrew, P.G. 1995. Implementing TPM: The North American Experience. Productivity Press.

Russell, R.S. & Taylor, B.W.2003. Operations Management. (4th ed). Upper Saddle River: Prentice Hall.

Rubrich, L & Watson, M. 2000. Implementing World Class Manufacturing. Fort Wayne: WCM Associates.

Saunders, M., Lewis, P. and Thornhill, A. 2000. Research Methods for Business Students. Pitman, London.

Schultz, H., Bagraim *et al*. 2003. Organisational behaviour: A contemporary South African perspective. Pretoria: Van Schaik.

Schroeder, R.G. 1993. Operations Management, Decision Making in the Operations Function. (4th ed). McGraw-Hill, New York.

Tuckman, B. and Jenson, M.A. 1977. Stages of small group developed revisited. Group and Organisational Studies, pp. 419-27.

Todd, J. 1995. World-class manufacturing. London: McGraw-Hill.

Tsang, A.H.C. 2002. Strategic dimensions of maintenance management. Journal of Quality in Maintenance Engineering, Vol. 80, No 1, pp 7-39.

Venkatesh, J. 1996 - 2005. An Introduction to Total Productive Maintenance. Plant Maintenance Resource center.

Ward, P.T., Duray, R., Leong, G.K., Sum, C.C. 1995. Business Environment, Operations strategy and performance: an empirical study of Singapore manufacturers. Journal of Operations Management, Vol.13, pp 99-115.

Wireman, T. 1991. Total Productive Maintenance: An American Approach. Industrial Press Inc.,New York.

Womack, J.P, Jones, D.T. & Roos, D. 1990. The machine that changed the world. New York: Rawson Associates.

Womack, J.P, Jones, D.T. & Roos, D. 2003. Lean Thinking. New York: Free Press.

**Internet sources:**

Daimler Chrysler [online]. Available from: http://www.daimlerchrysler.co.za/portalsintegra/modules_fe/layout1/displayFul/(accessed 22 September 2006).

Quantitative and qualitative research [online]. Available from: http://uk.geocities.com/balihar_sanhera/ipsrmehrigiulqualitativequantitativeresearch/(accessed: 01 September 2006).

## ANNEXURE A

## QUESTIONNAIRE COVERING LETTER

Dear Respondent

**RE: Questionnaire - The impact of Total Productive Maintenance (TPM) on manufacturing performance at your company.**

I hereby request for your assistance in filling the attached questionnaire. The questionnaire is part of my research paper for the requirements of a Masters Degree in Business Administration (**MBA**) at the Nelson Mandela Metropolitan University (**NMMU**).

I am currently conducting a survey on the impact of Total Productive Maintenance (**TPM**) on manufacturing performance at your company and your assistance in filling and returning the attached questionnaire by 15 September 2006 would be greatly appreciated. It should only take a few minutes of your time.

For further information and any queries I can be contacted on (043) 7311634 or 0731548456.

Yours faithfully,

**Mfowabo Ncube**
…….
**Researcher**
**Nelson Mandela Metropolitan University**

***Promoter: Prof. J.J. Pieterse (NMMU).***

## ANNEXURE B

## RESEARCH QUESTIONNAIRE

Please read the instructions for each section and answer the questions accordingly.

There is **NO** right or wrong answer to these questions and this is by **NO** means a test, it is merely a survey to obtain a better understanding of your environment with regards to Total Productive Maintenance (TPM) and manufacturing performance.

Total Productive Maintenance (TPM) is a manufacturing-led initiative that creates a collaborative approach between production and maintenance departments in an effort to achieve production efficiency, uninterrupted operations and ensure a quick, proactive maintenance response to prevent equipment problems.

**SECTION A: Measurement of Total Productive Maintenance (TPM)**

Instruction:

Please mark the appropriate box with an **X**

1. Total Productive Maintenance (TPM) principles are currently applied at your organisation.

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

2. Through TPM the need for preventive maintenance at your company is determined for every machine.

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

3. At your company, TPM improves planned maintenance systems.

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

4. TPM improves the quality of maintenance and hence productivity.

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

5. TPM addresses cleanliness and workplace organisation – eliminating dust, dirt and disarray.

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

6. Production operators at your company have accepted that autonomous maintenance is their responsibility. Autonomous maintenance is an element of TPM where operators practice taking ownership of their equipment.

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

7. Shop floor workers are organised in TPM teams for problem solving and the team objectives are aligned with departmental objectives.

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

8. All the TPM teams are empowered to take responsibility for their decisions.

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

9. TPM unlocks the potential of the workforce through an increase in skills and knowledge.

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

10. With TPM, workers are routinely involved in some organised form of continuous improvement activity (Kaizen).

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

11. At your company, the maintenance department focuses on assisting production operators for TPM activities.

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

12. Total Productive Maintenance improves teamwork between production and maintenance departments.

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

13. Top management strongly encourages employee involvement on TPM activities at your company.

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

14. Total Productive Maintenance improves equipment availability at your company.

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

15. Total Productive Maintenance improves equipment reliability so as to improve or replace machinery elements which are not robust and reliable.

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

16. Through TPM, machine speed losses are continuously detected at your company.

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

17. Total Productive Maintenance at your company strives for zero breakdowns.

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

18. TPM improves manufacturing performance through chronic loss analysis.

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

19. At your company TPM focuses on health, safety and environmental issues.

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

20. TPM ensures that plant and equipment are used to their maximum effectiveness.

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

21. At your company, charts plotting the frequency of machine breakdowns are posted on the shop floor.

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

22. TPM provides visibility to all major losses that are a result of poor equipment performance.

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

23. At your company, TPM reduces maintenance costs.

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

24. TPM works to reduce process defects at your company.

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

25. At your company, Total Productive Maintenance is implemented by various departments (engineering, operations, and maintenance).

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

26. At your company, Total Productive Maintenance involves every single employee, from top management to workers on the shop floor.

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

**SECTION B: Manufacturing performance goals**

Instructions:

Please mark the appropriate box with an **X.** The box represents a "Yes" or "No" – abbreviated "**Y**" and "**N**".

Does your organisation set specific numeric targets for the following performance measures?

1. CUSTOMER PERCEPTION

| Y | N |
|---|---|
| | |

   - Customer perceived quality
   - Customer complaints

2. DELIVERY

| Y | N |
|---|---|
| | |

   - On- time delivery
   - Fast delivery

3. QUALITY

| Y | N |
|---|---|
| | |

   - Cost of scrap
   - Rework
   - Defects

4. CYCLE TIME

| Y | N |
|---|---|
| | |

   - manufacturing lead time
   - work station setup time

**SECTION C: Demographic information**

Please mark the appropriate box with an **X**

1. What is your highest qualification?

| | |
|---|---|
| High School | |
| Diploma or Bachelor's degree | |
| Honour's degree | |
| Master's degree | |
| Doctorate | |

2. What is your position in this organisation?

| |
|---|
| |

3. How many years have you been involved in Total Productive Maintenance (TPM)?

| |
|---|
| |

**THANK YOU FOR YOUR SUPPORT**