THE FACTORS THAT HINDER THE OVERALL EQUIPMENT EFFECTIVENESS AT FORD STRUANDALE ENGINE PLANT

By

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ABSTRACT

This treatise investigates the underlying factors that are hindering the improvement of Overall Equipment Effectiveness at the Ford Struandale Engine Plant.

In January of 2008 the Ford Motor Company announced plans to invest more than R1.5 billion to expand operations for the production of Ford's next-generation compact pickup truck and the PUMA diesel engine. Ford will use the investment to expand operations both in Silverton for the production of 75 000 units of a new bakkie and in Port Elizabeth for 220 000 units of its new-generation PUMA diesel engines (http://www.autoblog.com /2008/01/31/ford-to-invest-209m-in-south-africa-for-new-ranger-pickup/).

Only five Ford plants globally will be producing the PUMA engine (Turkey, UK, Thailand, Argentina and South Africa – Ford Struandale Engine Plant). The Ford Struandale Engine Plant will be the only plant which will have the I4 assembly, I5 assembly and 3C (Crank, Cylinder Block, and Cylinder Head) machining and the expectations of operating in a lean environment is high.

The management team at the Ford Struandale Engine Plant needs to understand what the underlying factors that are hindering the improvement of Overall Equipment Effectiveness of the plant or, in other words, they need to be informed of the total benefits of TPM.

A literature review was conducted to determine what the theory reveals about Overall Equipment Effectiveness, the three factors of OEE (Availability, Performance Efficiency, and Quality), the influence of Six Big Losses on each of the factors and the role of Total Productive Maintenance in improving OEE by eliminating these Six Big Losses. A Ford literature study was conducted to reveal the current literature being applied at Ford. This was then followed by an empirical survey conducted within the Ford Struandale Engine Plant. In addition, a task team formed to analyse the current maintenance operating strategy.

Finally, the findings from discussions with the task team, the empirical survey, Ford Struandale Engine Plant literature survey and a general literature survey were amalgamated to draw conclusions relating to the Ford Struandale Engine Plant. These conclusions indicate what the underlying factors are that are hindering the improvement of Overall Equipment Effectiveness of the Ford Struandale Engine Plant facilities and equipment. Then recommendations are made as to how the Ford Struandale Engine Plant can improve the Overall Equipment Effectiveness of its facilities and equipment.

ABBREVIATIONS

AM	Autonomous Maintenance
APQP	Advanced Product Quality Planning
CCAR	Concerns Corrective Action Report
CPU	Cost per unit
EAP	Employee Assistance Programme
ECPL	Energy Control and Power Lockout
FAR	Failure Analysis Report
FMCSA	Ford Motor Company of Southern Africa
FMEA	Failure Mode and Effect Analysis
FPS	Ford Production System
FRACAS	Failure Reporting, Analysis and Corrective Action System
FSEP	Ford Struandale Engine Plant
FTPM	Ford Total Productive Maintenance
G8D	Global Eight Discipline
GPDS	Global Product Development System
ISPC	In station Process Control
JIT	Just In Time
MP	Maintenance Prevention
MP&L	Material Planning and Logistics
MTBF	Mean Time between Failures
MTC	Manage the Change
MTTR	Mean Time to Repair
NWG	Natural Work Group meeting
OEE	Overall Equipment Effectiveness
OSHA	Occupational Health and Safety Act
PD	Predictive Maintenance
PDCA	Plan Do Check Action
PM	Planned Maintenance
PPAP	Production Part Approval Process
PPE	Personal Protective Equipment

PQCDSM	Product; Quality; Cost; Delivery; Safety, health and environment; Morale
PTO	Power Train Operations
QM	Quality Maintenance
QOS	Quality Operating System
R&M	Reliability and Maintainability
SGA	Small Group Activities
SMED	Single Minute Exchange of Dies
SPC	Statistical Process Control
SQDCME	Safety Quality Delivery Cost Morale Environment
STA	Supplier Technical Assistance
SWOT	Strengths Weaknesses Opportunities Threats
TEM	Total Equipment Management
TOPS	Team Oriented Problem Solving
TPM	Total Productive Maintenance
TQM	Total Quality Management
TRS	TEM Reporting System
VSM	Value Stream Maps
WRP	Warranty Reduction Programme

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CHAPTER ONE
PROBLEM DEFINITION AND KEY CONCEPTS

1.1 INTRODUCTION

The foundation of any successful journey towards lean manufacturing is equipment stability and the best tool to date that manufactures can use to improve the predictability and stability of their equipment is Total Productive Maintenance (Bernstein, 2005:84). Total Productive Maintenance is a Japanese approach to maximising the effectiveness of the facilities used in a business. It not only addresses maintenance but all aspects of the operation and installation of these facilities and at its very heart the motivation and enhancement of the people who work in the company (Davis, 1995:1).

Suzuki (1992:X) stated that as a maintenance philosophy TPM has as much to do with the attitude of employees as it does with maintenance skills. It also gives the production people a new sense of ownership and pride in the equipment as they learn the importance of cleaning and inspecting the equipment. In addition, a partnership develops between the maintenance employees and equipment operators, so together they can detect early warnings of failure and take corrective action.

Total Productive Maintenance (TPM) is usually one part of a broader lean initiative, and its goal is usually to improve equipment uptime and reliability (Bernstein, 2005:1). In the past few years FMCSA Struandale Engine Plant (Port Elizabeth) has implemented Total Productive Maintenance as an element of its lean manufacturing which is known as Ford Production Systems (FPS). Since the implementation of TPM there is a concern that although the uptime and machine availability have improved, the efficiencies are flat.

Total Productive Maintenance is not just a way of improving machine reliability. It is an investment in a company that produces significant benefits which can and should be measured (Bernstein, 2005:21). Overall Equipment Effectiveness (OEE) is a matrix used in implementing TPM to evaluate how well equipment is used. It is important to have comprehensive data, clear goals and an organisational structure to support TPM activities.

The purpose of this study is to improve Overall Equipment Effectiveness at FMCSA Struandale Engine Plant (Port Elizabeth) by investigating the factors which influence Overall Equipment Effectiveness.

1.2 PROBLEM STATEMENT

In January of 2008 Ford Motor Company announced plans to invest more than R1.5 billion to expand operations for the production of Ford's next-generation compact pick-up truck and the PUMA diesel engine. Ford will use the investment to expand operations in Silverton to produce 75 000 units of a new bakkie and in Port Elizabeth to produce 220 000 of its new-generation PUMA diesel engines.

Only five global plants will be producing the PUMA engine (Turkey, UK, Thailand, Argentina and South Africa – Ford Struandale Engine Plant). The Ford Struandale Engine Plant will be the only plant which will have the I4 assembly, I5 assembly and 3C (Crank, Cylinder Block, and Cylinder Head) machining and the expectations of operating in a lean environment is high. As indicated before, the foundation of any successful journey towards lean manufacturing is equipment stability and the best tool to date that manufacturers can use to improve the predictability and stability of their equipment is Total Productive Maintenance (Bernstein, 2005:84). Therefore the management team needs to understand what the underlying factors are that are hindering the improvement of overall equipment effectiveness of the plant or total benefits of TPM. Based on the above-mentioned situation, the researcher has come up with the following problem statement:

What are the underlying factors that are hindering the improvement of Overall Equipment Effectiveness at Ford Struandale Engine Plant?

1.3 RESEARCH OBJECTIVES

Primary objective

The primary objective of this study is to improve Overall Equipment Effectiveness (OEE) at Ford Struandale Engine Plant by investigating factors that influence OEE.

Secondary objectives

In order to address the above-mentioned challenge, the following secondary objectives need to be investigated:

- What the literature reveals in terms of how to calculate OEE;
- What are the contributing factors that influence OEE;
    - Availability
    - Performance efficiency
    - Quality rate
- What the impact is of the Six Big Losses on OEE;
    - Breakdown losses
    - Setup and adjustment losses
    - Idling and minor stoppage losses
    - Reduced speed losses
    - Startup rejects
    - Production rejects
- What is the Ford Struandale Engine Plant performance on each of these aspects;
    - Availability
    - Performance efficiency
    - Quality rate
- What impact does training have on OEE at Ford Struandale Engine Plant;
    - What employees at Ford Struandale Engine Plant feel
    - What Ford Struandale Engine Plant has done
- Ford Struandale Engine Plant has programmes to improve OEE. These programmes include:
    - Ford Total Productive Maintenance
    - Human factors
    - Quality factors

    What their effectiveness is

1.4 DELIMITATION OF THE RESEARCH

According to Collis and Hussey (2003), delimitation explains how the scope of a study is focused on one particular area.

1.4.1 The Organisation

This research will be conducted at Ford Motor Company of South Africa Struandale Engine Plant, an engine manufacturing plant, located in Port Elizabeth. This plant consists of two production areas: the engine component machining area and the engine assembly area.

1.4.2 Geographic Delimitations

The research will be limited to the Ford Struandale Engine Manufacturing Plant, located in Port Elizabeth. This does not include the Silverton vehicle assembly plant, which is located in Pretoria. The empirical component of this study was limited to hourly employees, team leaders and artisans (electricians and fitters) of the Struandale Engine Plant.

1.4.3 Advanced Product Quality Planning (APQP)

The Supplier APQP/PPAP Readiness Assessment (Schedule A) is a structured method for defining and executing the actions necessary to ensure that a product satisfies the customer. APQP/PPAP Readiness is program and supplier-led and is required of all system, subsystem and component manufacturing locations.

The goal of APQP/PPAP Readiness is to facilitate communication between all persons and activities involved in a programme and to ensure that all required steps are completed on time, with a high quality-of-event, at acceptable cost and quality levels.

APQP and PPAP will not be discussed in detail in this research. This is the process that is very closely followed by Ford in engaging suppliers and ensuring quality levels and acceptable cost. It is one of Ford's internal programmes used to manage the change.

1.5 KEY ASSUMPTIONS

i) Assumption one

It is assumed that Ford Motor Company of South Africa's Struandale Engine Plant, in order to produce a PUMA diesel engine that will be competitive nationally and internationally, will have to reduce cost and improve quality and overall equipment effectiveness and utilisation. The PUMA diesel engine is the global engine that Ford Struandale Engine Plant will be producing and exporting to other countries by 2011. The Ford Struandale Engine Plant will be the only plant which will have the I4 assembly, I5 assembly and 3C (Crank, Cylinder Block, Cylinder Head) machining. The I4 2.2 L and the I5 3.2 L diesel engine will also be produced for the T6 bakkie that will be produced in Silverton, Pretoria.

ii) Assumption two

It is assumed that the management of Struandale Engine Plant is committed and has motivated, involved and committed employees to make the necessary improvements.

iii) Assumption three

It is assumed that Ford management and the readers have a high level of knowledge and understanding of Total Productive Maintenance.

1.6 METHODOLOGY

Methodology refers to the overall approach to the research process, from the theoretical underpinning to the collection and analysis of the data (Collis & Hussey, 2003:55).

1.6.1 Research paradigm

According to Collis and Hussey (2003), there are two main research paradigms. These are positivist (quantitative) and phenomenological (qualitative) paradigms.

A phenomenological study is a study that attempts to understand people's perceptions, perspectives, and understanding of a particular situation (Leedy & Ormrod, 2001:153). Qualitative research believes that the researcher's ability to interpret and make sense of what he or she sees is critical for an understanding of any

social phenomenon (Leedy & Ormrod, 2001:147). The researchers also believe that there is not necessarily a single, ultimate truth to be discovered. Instead, there may be multiple perspectives held by different individuals, with each of these perspectives having equal validity, or truth (Creswell, 1998: Guba & Lincoln, 1988). Qualitative research is typically used to answer questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participants' point of view (Leedy & Ormrod, 2001:101).

Quantitative research is used to answer questions about relationships among measured variables with the purpose of explaining, predicting and controlling phenomena. This approach is sometimes called the traditional, experimental, or positivist approach (Leedy & Ormrod, 2001:101).

The quantitative research is used to answer questions about relationships among measured variables and it usually ends with confirmation or disconfirmation of the hypotheses that will be tested.

According to Remenyi, Williams, Money and Swartz (1998), it is then claimed that qualitative research is "soft" research, and therefore can only add little to the real body of knowledge except in so far that it suggests new directions for quantitative or hard research. They further emphasised that it is important to remember that qualitative research and the construction of narratives that embrace the essential features of the problem can contribute substantially to the body of knowledge even if one hopes eventually to go beyond this with the use of quantitative techniques.

The purpose of this study is to improve Overall Equipment Effectiveness (OEE) of the organisation under consideration by investigating factors that influence OEE.

Combined elements of both approaches have been adopted in this study. According to Leedy and Ormrod (2001:103), by making the distinction between quantitative and qualitative research, it is not meant to imply that these approaches are mutually exclusive – that a researcher must choose to use one or the other of these for any particular study. In fact, researchers often combine elements of both approaches.

1.6.2 The sampling design

A sample is made up of some of the members of the population. A population may refer to a body of people or to any other collection of items under consideration for research purposes (Collis & Hussey, 2003:155). The sample should be carefully chosen so that, through it, the researcher is able to see all the characteristics of the total population in the same relationship that they would be seen were the researcher, in fact, to impact the total population (Leedy & Ormrod, 2001:211).

Successful statistical practice is based on focused problem definition. In sampling, this includes defining the population from which the sample is drawn. A population can be defined as including all people or items with the characteristic one wish to understand. Because there is very rarely enough time or money to gather information from everyone or everything in a population, the goal becomes finding a representative sample (or subset) of that population (http://en.wikipedia.org/wiki/ Sampling)

In this study there are two types of sampling that will be used: snowball and stratified sampling. Snowball sampling is used when constructing the questionnaires directed at artisans and the team leader. The snowball sampling or networking is associated with phenomenological studies where it is essential to include people with experience of the phenomena being studied in the sample (Collis & Hussey, 2003:158). Stratified sampling will be used as the sampling frame which consists of the following strata: electricians, fitters and team leaders. The total population consists of 46 participants: eight electricians, 15 fitters, and 23 team leaders. Confidentiality will be guaranteed to all the respondents. The researcher will also work closely with Human Resources to ensure that all the unethical issues are dealt with before the study commences.

The sampling processes and procedures allow the researcher to make better and informed decisions on the basis on information received from the sample.

1.6.3 Data Collection

The primary data was collected by means of questionnaires. The questionnaire used in this research has been formatted according to the five-point Likert Scale that ranges from (1) Strongly Disagree to (5) Strongly Agree.

Secondary data was obtained from a number of literature sources, including published articles, company documents (work instructions, policies, monthly reports, processes and procedures and the company intranet). A full and comprehensive description of the method of the study and motivation is given in chapter four.

Annexure B indicates the types of questions that are included in the chosen data collection method.

1.6.4 Data Analysis

Data analysis is a process of gathering, modeling, and transforming data with the goal of highlighting useful information, suggesting conclusions and supporting decision-making. Data analysis has multiple facets and approaches, encompassing diverse techniques under a variety of names, in different business, science and social science domains (http://en.wikipedia.org/wiki/Data_analysis). The data collected by the questionnaires will be analysed using Excel spreadsheet.

1.7 TERMINOLOGY DESCRIPTION

Autonomous Maintenance

Autonomous Maintenance involves the participation of every operator, each maintaining his or her own equipment and conducting activities to keep it in the proper condition and running correctly. It is a process by which equipment operators accept and share responsibility (with maintenance) for the performance and health of their equipment (Robinson & Ginder, 1995:57).

Continuous Improvement

Continuous improvement simply means never resting on one's laurels. Regardless of the product or service, it can always be improved. What may be "good enough" today will very soon be outdated, unusable and old-fashioned (Haberer & Webb, 1994:3).

Data Collection

Data collection is a term used to describe a process of preparing and collecting data. A formal data collection process is necessary as it ensures that data gathered is both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid. The process provides both a baseline from which to measure from and in certain cases a target on what to improve (http://en.wikipedia.org/wiki/Data_collection).

Lean Manufacturing

"A systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection." (http://www.leanqad.com/education/what_lean.html)

Lean manufacturing aimed at bringing together human, material and mechanical resources at the right time and place to accomplish a task. It strived to eliminate every kind of waste including wastage of time, labour, scrap material and defective parts (http://www.icmrindia.org/casestudies/catalogue/Operations/Ford%20Production%20System-Operations%20Management%20Case%20Study.htm).

Management buy-in

Total Productive Maintenance will not work unless the implementation programme is given the wholehearted backing of the management team in terms of actions, not words (Davis, 1995:68). Top and middle managers must fully understand why their company, business unit or plant needs to implement TPM (Suzuki, 1992:31).

Overall Equipment Effectiveness

OEE is the primary metric of TPM. It indicates a single piece of equipment's actual contribution as a percentage of its potential to add value to the value stream. The

calculation is: % availability × % standard run rate (performance efficiency) × % first pass quality (Bernstein, 2005:66).

Questionnaire

A questionnaire is a method of collecting data in which a selected group of participants are asked to complete a written set of structured questions to find out what they do, think or feel. It is a list of carefully structured questions, chosen after considerable testing, with a view to eliciting reliable responses from a chosen sample (Collis & Hussey, 2003:173).

Snowball sampling

Snowball sampling is a special non-probability method used when the desired sample characteristic is rare. It may be extremely difficult or cost prohibitive to locate respondents in these situations. Snowball sampling relies on referrals from initial subjects to generate additional subjects. While this technique can dramatically lower search costs, it comes at the expense of introducing bias because the technique itself reduces the likelihood that the sample will represent a good cross section of the population (http://www.statpac.com/ surveys/sampling.htm).

Total Productive Maintenance

Total Productive Maintenance is a Japanese approach to maximising the effectiveness of the facilities used within a business. It not only addresses maintenance but all aspects of the operation and installation of these facilities, and at its very heart the motivation and enhancement of the people who work in the company (Davis, 1995:1). The three components of TPM are as follows (Davis, 1995:1):

i). Total approach: An all-embracing philosophy which deals with all aspects of the facilities employed within all areas of an operating company and people who operate, set up and maintain them.

ii). Productive action: A very pro-active approach to the condition and operation of facilities, aimed at constantly improving productivity and overall business performance.

iii). Maintenance: A very practical methodology for maintaining and improving the effectiveness of facilities and the overall integrity of production operations.

Training

Training in equipment maintenance and operation identifies the specific knowledge, skills and management abilities people should have so the right training programmes can be designed to instill them (Bernstein, 2005:53).

World Class Manufacturing

World Class Manufacturing is a different set of concepts, principles, policies and techniques for managing and operating a manufacturing company. World Class Manufacturers are those that demonstrate industry best practice. To achieve this, companies should attempt to be best in the field at each of the competitive priorities (quality, price, delivery speed, delivery reliability, flexibility and innovation). Organisations should therefore aim to maximise performance in these areas in order to maximise competitiveness (http://www.smthacker.co.uk/world_class_manufacturing.htm).

World Class Manufacturing is a process-driven approach where implementations usually involve the following philosophies and techniques: Make-to-order; Streamlined flow; Small lot sizes; Families of parts; Doing it right the first time; Cellular manufacturing; Total preventative maintenance; Quick changeover; Zero Defects; Just-in-time; Variability reduction; High employee involvement; Cross-functional teams; Multi-skilled employees; Visual signaling and Statistical process control (http://rockFordconsulting.com/world-class-manufacturing.htm).

1.8 OUTLINE OF THE STUDY

The study will be divided into five chapters.

Chapter One will outline the scope of the study, the problem statement, the objectives, key assumptions, methodology, the importance of the topic as well as provide a description of the approach, delimitations and the proposed chapter headings of the research treatise.

Chapter Two will provide a literature overview on the Overall Equipment Effectiveness which includes Overall Equipment Effectiveness, availability, performance effectiveness, quality rate, the Six Big Losses and an overview of TPM.

Chapter Three will outline the Ford Struandale Engine Plant literature review on the Overall Equipment Effectiveness which includes availability, performance effectiveness, quality rate, the Six Big Losses and an overview of TPM.

Chapter Four will outline the research methodology, which includes the research paradigm, sampling design and measuring instruments.

Chapter Five, the results will be presented and discussed.

Chapter Six will consist of conclusions and recommendations.

1.9 SUMMARY

This chapter introduced the research problem to be investigated as well as secondary objectives. The delimitation of the research was discussed which covered organisation, level and geographical area. The three key assumptions, research methodology which includes sampling size and measuring instruments, were also discussed. Definitions of the terms used in the research were provided as well as the significance of the research. The research design was outlined for this study.

Chapter two will provide a literature overview of Overall Equipment Effectiveness which includes Overall Equipment Effectiveness, availability, performance effectiveness, quality rate, the Six Big Losses and an overview of total productive maintenance.

CHAPTER TWO
LITERATURE OVERVIEW

2.1 INTRODUCTION

An outline of the research paper was given in chapter one. The primary objective and the secondary objectives that need to be solved were also stated.

In this chapter the researcher will review the literature available for Overall Equipment Effectiveness, availability, performance efficiency, quality, Six Big Losses and Total Productive Maintenance. The chapter will commence with the introduction and end with a brief summary.

The effectiveness of facilities has a direct bearing upon the competitiveness and profitability of a business and maximising their effectiveness means that the best possible return is generated by each capita asset owned by the business (Davis, 1995:35).

The object of production improvement activities is to increase productivity by minimising input and maximising output. More than sheer quantity, "output" includes improving quality, reducing costs and meeting delivery dates while increasing morale and improving safety and health conditions and the working environment in general (Nakajima, 1988:12).

There is a relationship between input and output in production activities. Input consists of labour, machines, and materials, while output comprises production (P), quality (Q), cost (C), delivery (D), safety, health and environment (S), and morale (M) (Nakajima, 1988:12).

Total Productive Maintenance (TPM) strives to maximise output (PQCDSM) by maintaining ideal operating conditions and running equipment effectively. A piece of equipment that suffers a breakdown, experiences periodic speed losses, or lacks precision and produces defects is not operating effectively. TPM strives to achieve overall equipment effectiveness by maximising output while minimising input (Nakajima, 1988:14).

To achieve overall equipment effectiveness, TPM works to eliminate the “Six Big Losses” that are formidable obstacles to equipment effectiveness (Nakajima, 1988:14).

To represent actual equipment operating conditions accurately, all six equipment losses must be include in the calculations. TPM includes all six of the big equipment losses in its calculation. It measures Overall Equipment Effectiveness by multiplying availability and performance efficiency by the rate of quality products. This measure of Overall Equipment Effectiveness combines the factors of time, speed and quality of the equipment operation and measures how these factors can increase added value (Nakajima, 1988:24).

2.2 OVERALL EQUIPMENT EFFECTIVENESS

The effectiveness of facilities has a direct bearing upon the competitiveness and profitability of a business and maximising their effectiveness means that the best possible return is generated by each capital asset owned by the business (Davis, 1995:35).

Overall Equipment Effectiveness is the primary metric of Total Productive Maintenance. It indicates a single piece of equipment's actual contribution as a percentage of its potential to add value to the value stream (Bernstein, 2005:66).

OEE provides the means to evaluate the production process by measuring the effective utilisation of the capital assets. The goal of OEE is to eliminate the Six Big Losses. The relationship between the six process losses and OEE are shown in table 2.2.

Gupta, Tewari and Sharma (2006) conclude that overall equipment effectiveness (OEE) incorporates not only availability but also performance rate and quality rate. In other words, OEE addresses all losses caused by the equipment’s not being available when needed due to breakdowns or set-up and adjustment losses; not running at the optimum rate due to reduced speed or idling and minor stoppage losses and not producing first pass quality output due to defects and rework or start-up losses. A key objective of TPM is to cost effectively maximise overall equipment effectiveness through the elimination or minimisation of all these six losses.

Overall Equipment Effectiveness, or OEE, offers a simple numerical representation of what is causing the inefficiency gap, providing daily information about how effectively equipment is running and which of the six loss areas needs improvement (OEE is represented as Availability Rate × Performance Rate × Quality Rate). Breaking these constituent parts into the Six Big Losses enables producers to not only calculate a holistic performance metric but to also delve into the underlying categories affecting performance. This proven framework has enabled hundreds of manufacturing organisations to determine, with great precision, the root cause of their inefficiencies. It provides the necessary structure for tackling the problems, improving efficiency and capacity, driving down costs and improving profitability. For manufacturers focused on removing capacity constraints, the framework can also help unlock additional capacity while reducing manufacturing costs and improving profitability (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

According to Bernstein (2005:101), OEE = availability rate × performance rate × quality rate. The availability rate expresses losses due to unplanned stoppages, the performance rate expresses losses due to machine performance lower than ideal or standard operating rates and the quality rate expresses losses due to rejects and reworks. Collecting and analysing OEE data is the basis of a systematic approach to reducing equipment-related losses. OEE should only be used on one piece of equipment within a process. The goal is to elevate the piece of equipment until it is no longer the constraint then move on to the next constraint in the process. This allows the company to focus its resources.

Generally, the bottleneck around the process has to be chased. When one bottleneck is improved, something else becomes the bottleneck. If all of the bottlenecks have been cleared and demand cannot be satisfied, then that is the time to consider whether more machines are needed. That is part of the power of OEE. By improving areas with low numbers that get in the way of output, capital investment can be deferred. Deferred capital investment is a wonderful way to save money for any organisation. It can be a financial incentive to calculate OEE (Bernstein, 2005:106).

When the machine is not a bottleneck, its capacity does not have to be increased. But OEE can still be useful in identifying ways to eliminate waste and reduce the cost of operation (Bernstein, 2005:111).

According to Davis (1995:37), overall effectiveness is a measure of all three of these factors (percentage availability, percentage performance, percentage quality) and, although it is not strictly a percentage, it is usually represented in percentage terms and is calculated as overall effectiveness = % availability × % performance efficiency × % quality. In practice, the generally accepted world class goals for each factor are quite different from each other, as is shown in the table 1 below (http://www.oee.com/world_class_oee.html).

Table 2.1: World class OEE

OEE Factor	World Class
Availability	90.0%
Performance	95.0%
Quality	99.9%
Overall OEE	85.0%

Source: http://www.oee.com/world_class_oee.html.

A world class OEE is considered to be 85% or better.

2.2.1 Availability

Availability can be defined as the ratio of full functional equipment to all reparable (functioning and nonfunctioning) equipment within a given period of time (Gotoh, 1991:9). For most equipment, the three major obstacles to availability are:

- Breakdowns
- Downtime for maintenance
- Changeovers

The first obstacle is a reliability issue and the second is a maintainability issue. If the definition of availability is broadened, it can be interpreted as a measure of effectiveness in capital investment (Gotoh, 1991:10).

- Availability drops when equipment is left idle as a result of reduction in production, cycle time imbalances, or other factors.
- Availability is also reduced when equipment is left idle because of product changes that result in product/equipment incompatibility.

These types of idle time, along with changeovers, are related mainly to changes brought about by market trends. Design for flexibility seeks to avoid obstacles to availability, including those resulting from product diversification and variable production yields. Equipment designs must flexibly accommodate change in the business environment as well as in the company's internal operations (Gotoh, 1991:10).

According to Davis (1995:35), percentage availability is the ratio of how long the machinery has actually been used over how long the machinery needs to be used and is calculated as:

$$\%\ \text{availability} = \frac{\text{loading time breakdown and set up time loss}}{\text{loading time}} \times 100$$

where loading time is the time that the machinery was planned to be in operation. Loading time may only be for a few hours a week, but if the machinery is required to be available for those few hours and is scheduled as such, then its percentage availability is based upon those few hours. Davis's preferred definition of loading time is:

loading time = planned production time - breaks - planned maintenance time

The operating rate is based on a ratio of operation time, excluding downtime, to loading time. The loading time or the available time per day (or month), is derived by subtracting the planned downtime from the total available time per day (or month). Planned downtime refers to the amount of downtime officially scheduled in the production plan, which includes downtime for scheduled maintenance and management activities (such as morning meetings). The operating time is derived by subtracting equipment downtime (non-operation time) from loading time; in other words, it refers to the time during which the equipment is actually operating.

Equipment downtime involves equipment stoppages losses resulting from failures, setup/adjustment procedures or the exchange of dies (Nakajima, 1988:22).

There are three major aspects of changeover from part to part which need to be considered in the changeover time reduction projects (Davis, 1995:92):

- The methods that are used to carry out the changeover, including all of the facilities used
- The design of tooling and how it is assembled to the machinery
- How the changes from part to part are scheduled.

It is quite usual to have the changeover time reduced mostly as a result of improved methods and some small hardware improvements. The changeover reduction project will bring about a substantial improvement in changeover time and thus in the availability of the machinery. Further continuous improvement activity should thereafter be used to keep gradually reducing changeover times and improving flexibility (Davis, 1995:93).

When machinery frequently breaks down due to a clearly identified cause, then the reliability improvement project team can begin to brainstorm solutions almost immediately, assess them and decide upon the most cost-effective solution. On many occasions, however, the situation is not so straightforward and the steps detailed below should be followed (Davis, 1995:93):

- Analyse the historical information on the machinery including the number, type and frequency of breakdowns and amount of time spent repairing the machinery.
- If insufficient information is available, arrange for information to be gathered over a period of time which will provide a typical set of results under normal operating conditions.
- Analyse the information: categorise the type of faults and problems encountered along with where they occur on the machinery or during the process and present them on a histogram.
- Discuss the findings and agree on the priority areas to be addressed.
- Analyse the faults using a structured problem-solving technique.

- Brainstorm solutions for dealing with the highest priority areas first.
- Decide upon the most cost-effective solution.
- Plan and implement the solutions.
- Move on to the next area and repeat steps 5 to 8, whilst still monitoring the performance of the machinery and the effects of the actions so far.

It is quite usual to find that there are just few areas and /or recurring faults which cause the majority of breakdowns and, by addressing these first, quite rapid benefits are achieved (Davis, 1995:94).

2.2.2 Performance Efficiency

Performance efficiency is the product of the operating speed rate and the net operating rate. The operating speed rate of equipment refers to the discrepancy between the ideal speed (based on equipment capacity as designed) and its actual operating speed (Nakajima, 1988:24).

The net operating rate measures the maintenance of a given speed over a given period. This figure cannot tell us, however, whether the actual speed is faster or slower than the design standard speed. It measures whether an operation remains stable despite periods during which the equipment is operated at a lower speed. It calculates losses resulting from minor recorded stoppages, as well as those that go unrecorded on the daily logs, such as small problems and adjustment losses (Nakajima, 1988:26).

According to Davis (1995:35), percentage performance is the ratio of what was actually produced in a given time over what would have been expected to be produced in a given time, and can be calculated in two ways. The first method is:

$$\%\,\text{performance} = \frac{\text{quantity produced}}{\text{time run} \times \text{capacity/given time}} \times 100$$

This is the most straightforward means of calculating percentage performance and is preferable where many products or bulk quantities are produced in a relatively short time. There are, however, situations where only a few parts are produced per day or per week or even per month or year. In these cases standard production times are

rarely used or accurate enough and therefore it is necessary to measure minor stoppages and reduced speed losses directly. In this case:

$$\%\ \text{performance} = \frac{\text{time run - minor stoppages - reduced speed}}{\text{time run}} \times 100$$

Note that the percentage performance figure can be calculated in either way, but it is usually simpler to use the first formula when reasonable quantities and standard throughput rates are available.

When the throughput of the process is significantly below what is expected, the project team will initially need to establish the possible causes of the problem. To accomplish this, the early stages are (Davis, 1995:96):

- Listing each activity that takes place during the operating cycle. This should include all machinery actuations, processing, operator activities and delays and can be carried out at a very dedicated level if necessary.
- Where possible, timing each activity or major group of activities with a stopwatch. Some machinery control systems can be programmed to time each activity and print out the results. The timing exercise should be carried out a number of times, at different times of the day and for different operators.
- Analysing the activities and their times, looking for trends and variations and also identifying the activities which take up the most significant amount of the cycle time.
- Base upon this analysis, identifying the particularly significant problems which are besetting the operation of the machinery.
- Establishing their root cause using one of the structured problem-solving techniques.
- Brainstorming the possible option and deciding upon the most cost-effective solution.
- Planning and implementing the improvement.

2.2.3 Quality Rate

Quality Rate is basically first run capacity or first run quality. It is the number of good parts minus defective parts produced without spending non-value added labour

(defective parts comprise scrap, re-worked parts and those used to set up the line) (http://hub.fmcsa.Ford.com/pe/FORD/FordStructure/ASPPages/FTPMpackages.asp.)

Percentage quality is the ratio of the number of good products over total products produced during a given period of time and, again, can be calculated in two ways (Davis, 1995:36). The first method is:

$$\%\,\text{quality} = \frac{(\text{amount produced}) - (\text{amount defects}) - (\text{amount re-processed})}{\text{amount produced}} \times 100$$

As with the percentage performance calculation, this is the most straightforward way of calculating percentage quality where many products or bulk quantities are produced. Where this is not the case, it may be necessary to record the amount of time spent producing reject parts or work and the amount of time spent re-processing parts. In this case the calculation is:

$$\%\,\text{quality} = \frac{(\text{time run}) - (\text{defect time}) - (\text{reprocessing time})}{\text{time run}} \times 100$$

Note that the percentage quality figure can be calculated in either way, but it is usually much simpler to use the first formula when the situation allows.

The prevention of defects at source is central to the philosophy of many world-class manufacturing businesses, and ‘poka-yoke’ or mistake-proofing is a proven approach to the elimination of many process quality problems. Poka-yoke is particularly relevant to production processes which involve a fair amount of operator interaction, and its aim is to ensure that things cannot go wrong. The improvement project team starts by identifying the work station or stages of the process where problems most often occur, along with the type of problems encountered. They then ask the question “How can we ensure that the problem cannot happen?”, brainstorm ideas and decide whether any of them are feasible. There are many types of poka-yoke devices with three main actions. The main action of the poka-yoke device is described as follows (Davis, 1995:97):

- Physical prevention of an error from happening such as restraints on a fixture which prevent the parts being incorrectly loaded (the pin configuration on many electrical plugs serves this same purpose) (Davis, 1995:97).

- Detection that an error has occurred and indication that it has happened such as sensors that check the orientation of parts and cause an audible or visual alarm to be activated (Davis, 1995:97).
- Detection that an error has occurred and prevention of the process from proceeding such as sensors that check the orientation of parts and send a signal to the machinery control system which inhibits its operation (Davis, 1995:97).

According to Davis (1995:37), overall effectiveness is a measure of all three of these factors (percentage availability, percentage performance, percentage quality) and, although it is not strictly a percentage, it is usually represented in percentage terms and is calculated as: overall effectiveness = % availability × % performance × % quality

2.3 SIX BIG LOSSES

Table 2.2: Defining the Six Big Losses

Six Big Loss Category	OEE Loss Category	Event Examples	Comment
Breakdowns	Down Time Loss	• Tooling Failures • Unplanned Maintenance • General Breakdowns • Equipment Failure	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	• Setup/Changeover • Material Shortages • Operator Shortages • Major Adjustments • Warm-Up Time	This loss is often addressed through setup time reduction programs.
Small Stops	Speed Loss	• Obstructed Product Flow • Component Jams • Misfeeds • Sensor Blocked • Delivery Blocked • Cleaning/Checking	Typically only includes stops that are under five minutes and that do not require maintenance personnel.
Reduced Speed	Speed Loss	• Rough Running • Under Nameplate Capacity • Under Design Capacity • Equipment Wear • Operator Inefficiency	Anything that keeps the process from running at its theoretical maximum speed (a.k.a. Ideal Run Rate or Nameplate Capacity).
Startup Rejects	Quality Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • Incorrect Assembly	Rejects during warm-up, startup or other early production. May be due to improper setup, warm-up period, etc.
Production Rejects	Quality Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • Incorrect Assembly	Rejects during steady-state production.

Source: http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf

Table 2.2 shows how the Six Big Losses relate to the OEE loss categories and gives typical reasons.

The six major equipment-related losses include breakdowns, setup and adjustment, idling and minor stoppages, process defects, re-works, and startup losses. From the equipment design standpoint, each of these losses can be converted to a quantified cost value. It is often easiest when designing the equipment, however, to look at the Six Big Losses in terms of their impact on the equipment capacity utilisation rate (Gotoh, 1991:60).

The Six Big Losses can be categorised under the following headings

Downtime losses

- Breakdowns losses
- Setup and adjustments losses

Speed losses

- Idling and minor stoppage losses
- Reduced speed loss

Quality losses

- Startup rejects
- Production rejects

Categorising data makes addressing the Six Big Losses much easier, and a key goal should be fast and efficient data collection, with data put to use throughout the day in real-time.

2.31 Downtime losses

(a) Breakdown losses

Breakdowns are by far the biggest of the Six Big Losses. There are two kinds: failed-function and reduced-function. Failed-function breakdowns tend to occur sporadically (suddenly), and they are easy to notice because they are relatively dramatic. On the other hand, reduced-function breakdowns enable the equipment to continue operating, but at a reduced level of efficiency. Very often reduced-function breakdowns can be discovered only by keen observation. But when they are overlooked, they give rise to idling and minor stoppages, rework, reduced speed, and

other problems, and they can become the cause of sporadic, failed-function breakdowns (Shirose, 1992:38).

In general, breakdowns are caused by all sorts of factors, but usually only the big defects are noticed and the myriad slight defects that also contribute to them are overlooked. Obviously, the big defects deserve attention, but the slight defects deserve equal attention because they accumulate, also causing breakdowns. In fact, many come about simply because seemingly minor things such as loose screws, abrasion, debris, and contaminants are ignored and their effects accumulate until they affect the efficiency of the equipment (Shirose, 1992:39).

When it comes to downtime, it is not enough to simply recognize that downtime is a problem. It is critical to also understand the causes for that loss. Furthermore, to drive change, it is important to break downtime up into its constituent parts. Besides reason codes, decision-makers need to know whether the downtime was caused by general wear and tear, operator error or maintenance technician delay, for instance. They also need to know how long the downtime lasted and how long it took for the operator to respond, for maintenance personnel to identify the problem, and for the operator to get the line up and running again (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

It is also important that the right people are empowered to make the data actionable. For instance, the operator may be the person reporting the observed fault or symptom, but it is the technician who can actually report the root cause. Both are needed to close the gap. And in most cases, the operator and the technician are the only individuals who can provide the key information needed to address root causes (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Finally, the data collected must be 100 percent accurate and that is where paper-based systems often fail. Trying to capture data manually requires that someone pick up a log at the end of the shift and report all the rate downtime they experienced during their shift. But in a fast-paced production environment, this is a futile task. The

chances of someone remembering every detail about the last eight hours are slim, which means that only a fraction of the data will ever be captured (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Eliminating unplanned downtime is critical to improving OEE. Other OEE Factors cannot be addressed if the process is down. It is not only important to know how much downtime the process is experiencing (and when) but also to be able to attribute the lost time to the specific source or reason for the loss (tabulated through Reason Codes). With downtime and Reason Code data tabulated**,** Root Cause Analysis is applied, starting with the most severe loss categories (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

(b) <u>Setup and adjustment losses</u>

These are losses caused by switching over from one product to another. Operations such as washing, purging, disinfecting, and charging with fresh materials often cause this type of loss (Suzuki, 1992:55).

Setup and adjustment losses are stoppage losses occurring during setup procedures such as retooling. Setup and Adjustment time is the time required for stopping current production and setting up for production of the next product. Adjustments tend to use the greatest amount of this time, and in any company these are of two types – difficult and unavoidable. In other words, people are loath to study adjustments and therefore seldom study them fully (Shirose, 1992:43).

Setup and Adjustment time is generally measured as the time between the last good parts produced before Setup to the first consistent good parts produced after Setup. This often includes substantial adjustment and/or warm-up time in order to consistently produce parts that meet quality standards (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Tracking Setup Time is critical to reducing this loss, together with an active programme to reduce this time (such as an SMED – Single Minute Exchange of Dies programme). Single Minute Exchange of Dies is a technique for reducing the setup times of equipment. Single Minute Exchange of Dies was developed by Shigeo Shingo to improve setup times in the Toyota production system. It is a simple technique that divides the elements of a setup task into internal activities (those that can be performed only when the machine is stopped) and external activities (those that can be performed in advance). Single minute refers to making the changes in less than ten minutes, while the exchange of dies comes from the steel presses that were the focus of Shingo's attention. By converting as many internal activities to external activities as possible, Shingo was able to reduce a four-hour setup time on a large press to less than ten minutes (http://dictionary.bnet.com/definition/single+minute+exchange+of+dies.html).

Many companies use creative methods of reducing Setup Time including assembling changeover carts with all tools and supplies necessary for the changeover in one place, pinned or marked settings so that coarse adjustments are no longer necessary, and use of prefabricated setup gauges (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

An operator with no changeover target and no real-time visibility into how he or she is performing against that target cannot be expected to work toward minimising changeover time. But in an environment in which equipment operators, supervisors and plant managers have full transparency into actual changeover times against targets, the dynamic is very different. When provided with an allowance detailing how long each changeover should take, a video clip or diagram that explains how to complete the changeover, and an end-of-shift report that provides detailed feedback on actual changeover performance against the target, operators tend to change their behaviour (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Greater clarity into root causes can also lead to significant performance improvements. The ability to analyse changeovers by crew, shift or product and to

easily determine when and where performance spikes are occurring allows managers to identify potential training issues. Analysis into setup time variability can also reveal causes that were previously unknown or simply ignored (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

2.3.2 Speed losses

(a) <u>Idling and minor stoppage losses</u>

These are losses incurred when equipment stops temporarily, not necessarily because it has broken down but because the flow or raw materials or parts have momentarily been obstructed. Idling and minor stoppages are usually defined as lasting five minutes or less (Suzuki, 1992:55).

Unlike ordinary breakdowns, idling and minor stoppages are caused by temporary problems in the equipment. For example, a workpiece may jam in a chute, or a quality control sensor may temporarily shut down the equipment. As soon as someone removes the jammed workpiece or resets the sensor, it operates normally again. Therefore idling and minor stoppages are qualitatively different from ordinary breakdowns, but they often interfere with efficiency, especially in an automated processing, assembly or conveyor machine (Shirose, 1992:44).

This category often represents a tremendous area for performance improvement. Idling and minor stoppages typically lead to other costly problems, in addition to lost time. In fact, even the smallest stoppage can kill the entire flow of a line in many production environments. Fortunately this is also one of the easiest areas to improve when the proper technology and feedback systems are in place. And in most cases, taking corrective action involves simple, painless changes in working practices rather than major capital investments. But to achieve positive, sustainable improvements in this area, information must be captured on a minute-by-minute basis. Moreover, it is important to establish a process by which shop floor personnel can quickly and easily indicate the reasons for stoppages as they occur. All too often operators have no way of communicating constant and repetitive line performance problems to senior management, so the problems continue unabated. It is also critical that the feedback

system be automated, not paper-based. Paper forms take too long to use in a fast-paced, real-time environment. They also lead to inaccuracies and discourage shop floor personnel from entering the information as it happens (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Because idling and minor stoppages can usually be restored quite simply, they tend to be overlooked and not regarded as loss. But they are indeed losses and this must be made obvious to everyone concerned (Shirose, 1992:43).

(b) <u>Reduced speed loss</u>

Reduced speed occurs when there is a difference between the speed at which a machine is designed to operate and its actual speed. For example, reduced speed loss occurs when operators intentionally slow a machine down because its designed speed results in quality defects or mechanical problems. Since reduced speed loss has a powerful impact on equipment efficiency, it should be fully investigated. Increasing the equipment speed is a good way to expose problems and therefore can help improve the technical skills needed to overcome these problems. Whether trying to eliminate breakdowns or defects, corrective actions against reduced speed loss are similar (Shirose, 1992:46).

Providing factory floor personnel with full, real-time visibility into line speed can have a dramatic effect on performance. Often referred to as the “Hawthorne effect” - a term used to describe behavioral changes when an individual knows his or her actions are being observed - improved performance is often immediate and significant. Naturally the objectives for most manufacturers include improvements in speed. But, in addition, the objectives should include the ability to achieve an optimal balance between efficiency and product quality. In that case, the organisation’s performance management system should enable comparisons between production runs of the same product and by different operators. This can help executives better understand what the line was actually running when the line speed decreased, so that a comparison can be made between variables such as operator,

speed and product quality (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Small Stops and Reduced Speed are the most difficult of the Six Big Losses to monitor and record. Cycle Time Analysis should be utilised to pinpoint these loss types. In most processes recording data for Cycle Time Analysis needs to be automated since cycles are quick and repetitive events that do not leave adequate time for manual data-logging (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

By comparing all completed cycles to the Ideal Cycle Time and filtering the data through a Small Stop Threshold and Reduced Speed Threshold, the errant cycles can be automatically categorised for analysis. The reason for analysing Small Stops separately from Reduced Speed is that the root causes are typically very different (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

2.3.3 Quality losses

(a) <u>Startup rejects</u>

Startup/yield losses are those incurred because of the reduced yield between the time the machine is started up and when stable production is finally achieved. Often startup/yield losses are difficult to identify and their extent varies with the stability of processing conditions, the readiness of jigs and dies, worker training, loss incurred by test operations and other factors. In any case, this usually adds up to significant loss (Shirose, 1992:48).

Startup Rejects and Production Rejects are differentiated, since often the root causes are different between startup and steady-state production. Parts that require re-work of any kind should be considered rejects. Tracking when rejects occur during a shift and/or job run can help pinpoint potential causes and in many cases patterns will be discovered. Often a Six Sigma programme, where a common metric is achieving a defect rate of less than 3.4 defects per million “opportunities”, is used to focus attention on a goal of achieving ”near perfect” quality

(http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Most manufacturers in process manufacturing environments experience a certain level of product loss in virtually every startup routine. However, if getting a line running at full running speed requires an operator to cycle the line two or three times, losing product in the process, there is generally an opportunity for improvement. By having greater visibility into the effect of different variables on overall performance, managers can better determine the startup conditions that are more conducive to waste, as well as the reasons for those conditions and how they can be addressed. Moreover, embedding the standard operating procedure into the process can help operators determine exactly how the equipment should be set up, drastically minimising the amount of waste during startup. Changeover alerts can also be helpful. For instance, notifying the operator that he or she should be running the equipment at a certain rate or temperature can help minimise these unnecessary losses during a changeover (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

(b) <u>Production rejects</u>

These are losses caused when equipment produces a product that deviated from the standard quality or specification (Suzuki, 1992:56).

This type of loss is incurred through quality defects and related re-work or repair. Among quality defects, those that occur sporadically are more easily understood and therefore easier to act against. As a result, they are seldom left untreated. By contrast, chronic defects are more difficult to understand, often resist corrective measures and are therefore often overlooked or ignored. Loss incurred by re-work and repair has a huge impact on equipment efficiency. Therefore action against it is one of the most important activities in an effort to eliminate the Six Big Losses (Shirose, 1992:47).

In terms of scrap and re-work, knowing the size of the loss is not enough. To improve performance, manufacturers also need an accurate indication as to the source of the

loss. To ensure that the minimum amount of product is scrapped, it is important to capture every single scrap instance as it occurs and note how each of those correlates with other variables at the time of the loss, such as actual temperature, humidity and other key production factors that could conceivably impact quality (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

Although the Six Big Losses can be found in every workplace, the relative proportion of each will vary depending on equipment characteristics, line configuration, automation conditions and other factors. For example, if the workplace has an abundance of setup/adjustment and breakdown loss, it will have an especially poor availability (operating rate). Likewise, a workshop fraught with idling and minor stoppages will have a particularly low performance rate (Shirose, 1992:54).

Therefore, at any workplace, the approach is to first find out which losses are having the greatest impact on equipment effectiveness, and then address the bulk of the improvement efforts towards those (Shirose, 1992:55).

2.4 TOTAL PRODUCTIVE MAINTENANCE

Total Productive Maintenance is a Japanese approach to maximising the effectiveness of the facilities used in a business. It not only addresses maintenance but all aspects of the operation and installation of these facilities, and at its very heart the motivation and enhancement of the people who work within the company (Davis, 1995:1). The three components of TPM are as follows (Davis, 1995:1):

i). Total approach: This is an all-embracing philosophy which deals with all aspects of the facilities employed within all areas of an operating company and people who operate, set up and maintain them.

ii). Productive action: This is a very pro-active approach to the condition and operation of facilities, aimed at constantly improving productivity and overall business performance.

iii). Maintenance: This is a very practical methodology for maintaining and improving the effectiveness of facilities and the overall integrity of production operations.

The essence of TPM is teamwork, focused on the condition and performance of particular facilities. The team is composed of people who operate, set up and maintain the facilities with, in some instances, the addition of people who are involved in the provision of planning or engineering support to the facility (Davis, 1995:1).

Suzuki (1992:X) stated that TPM as a maintenance philosophy has as much to do with the attitude of employees as it does with maintenance skills. It also gives the production people a new sense of ownership and pride in the equipment as they learn the importance of cleaning and inspecting the equipment. Also a partnership develops between the maintenance employees and equipment operators, so together they can detect early warnings of failure and take corrective action.

Total Productive Maintenance (TPM) is the maintenance sub-system of Lean Manufacturing. TPM improves manufacturing performance by reducing cost, improving quality and increasing productivity (tpm Strategosins.com). TPM is usually one part of a broader lean initiative, and its goal is usually to improve equipment uptime and reliability (Bernstein, 2005:3).

The key to a successful Total Productive Maintenance programme is not the actual maintenance activities. Sustaining an effective programme depends on everything that supports those activities: collection of accurate data, scorecards that show the significance of the data, clearly defined responsibilities for everyone involved and procedures that provide for ongoing support of TOM efforts (Bernstein, 2005:9).

2.4.1 The Goal of TPM

The goal of TPM is to effect fundamental improvement within a company by improving worker and equipment utilisation. To eliminate the Six Big Losses, people's attitudes must first be changed and their skills increased. Increasing their motivation and competency will maximise equipment effectiveness and operation. Such improvements in the quality and functioning of equipment and in one's mental outlook are essential to fundamental corporate improvement. Unless top management takes the lead by seriously tackling this issue, however, the necessary transformation

in attitudes, equipment and the overall corporate constitution will not progress smoothly (Nakajima, 1988:54).

TPM is designed to maximise equipment effectiveness (improving overall efficiency) by establishing a comprehensive productive maintenance system covering the entire life of the equipment, spanning all equipment-related fields (planning, use, maintenance, etc.) and, with the participation of all employees from top management down to shop-floor workers, promoting productive maintenance through "motivation management," or voluntary small-group activities. TPM aims at maintaining the optimal condition of equipment and upgrading maintenance skills (Tsuchiya, 1991:4). TPM is equipment-directed management. As such, it must lay an educational ground work that trains as many workers as possible in the fundamentals and key components of the equipment they use (Tsuchiya, 1991:4). Operators should maintain and inspect their machines as well as operate them, and maintenance personnel should not just be specialists in either mechanical or electrical systems but should understand both disciplines. The current situation requires that as many people as possible be trained in maintenance and improvement skills. As people master skills and become involved in planning, measurement, judgment, execution and improvement, they will develop a sense of satisfaction and achievement (Tsuchiya, 1991:8).

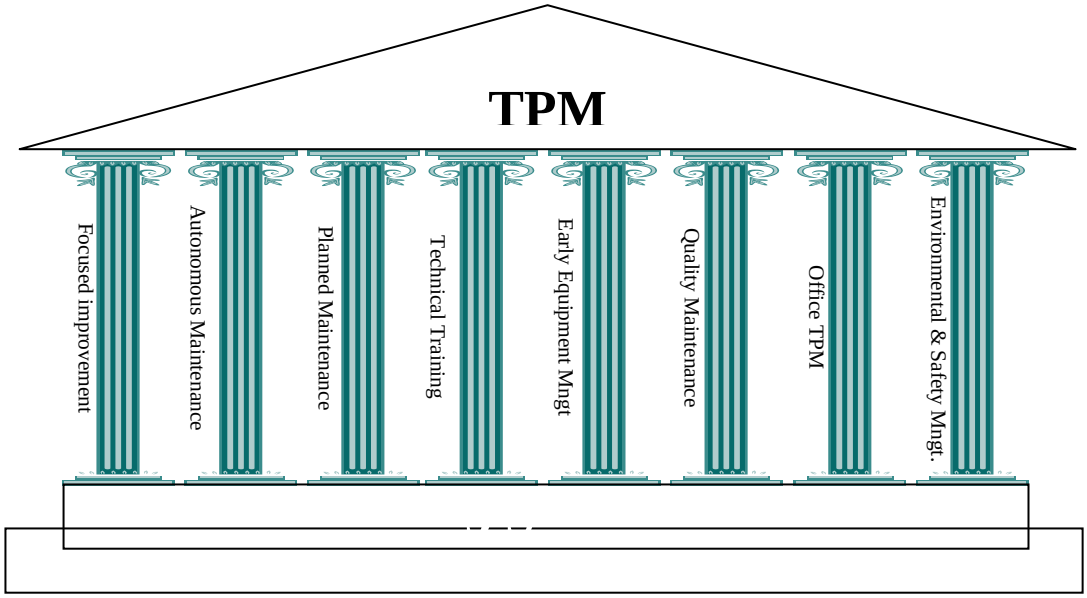
Bringing the whole company together behind TPM enables it to actually achieve goals such as zero breakdowns and zero defects, and these pay off in terms of higher productivity and enhanced profitability (Shirose, 1992:16).

2.4.2 The eight pillars of TPM development

The following eight activities are the most common ones for implementing TPM effectively and efficiently. When properly implemented, they form the foundation that will support any successful TPM effort. Not all of these strategies are implemented at once. Each company will develop a sequence that fits its situation (Bernstein, 2005:62).

Figure 2.1 below indicates the eight pillars of TPM development. These pillars will then be discussed in detail individually.

Fig 2.1: The eight pillars of TPM development



Source: Bernstein, 2005:62

(a) Focused improvement

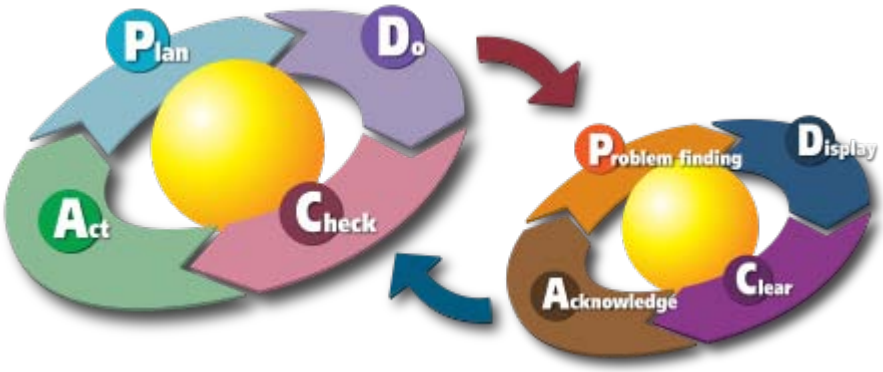
Focused improvement (*kaizen*) activities are performed by cross-functional teams composed of such people as production engineers, maintenance personnel and operators. These activities are designed to minimise targeted losses that have been carefully measured and evaluated (Bernstein, 2005:62).

Continuous process improvement means accepting small, incremental gains as a step in the right direction towards Total Quality (Jablonski, 1991:5). Continuous improvement simply means never resting on your laurels. Regardless of the product or service, it can always be improved. What may be "good enough" today will be outdated, unusable, and old-fashioned very soon (Haberer & Webb, 1994:3).

According to Imai (1986) there are certain characteristics of continuous improvement. The first principle is process orientation. Before results can be improved, it is the central tenet of continuous improvement that processes must be improved. Good results will follow automatically when processes are both understood and controlled. The second principle is small step improvement of work standards. Imai states it very decisively: "There can be no improvement where there are no standards" (Imai, 1986:74). Another aspect of this principle is the never-ending process of *kaizen*. It is

an ongoing process. This is symbolised in the PDCA problem-solving format for improvement: a wheel (International Journal of Operations and Production Management, 1999:1190).

Fig 2.2: The PDCA Cycle



Source: http://en.wikipedia.org/wiki/Total_Quality_Management

The PDCA-loop itself is a standardisation of the improvement process. The cycle of *kaizen* activity can be defined as:

- Standardizing an operation
- Measuring the standardised operation (find cycle time and amount of in-process inventory)
- Gauging measurements against requirements
- Innovating to meet requirements and increase productivity
- Standardising the new, improved operations
- Continuing the cycle ad infinitum.

The third principle is people-orientation. Continuous improvement needs the involvement of everyone in the organization, from shop floor workers to top management (International Journal of Operations and Production Management, 1999:1190).

Continuous improvement must deal not only with improving results, but more importantly with improving capabilities to produce better results in the future. The five major areas of focus for capability improvement are demand generation, supply

generation, technology, operations and people capability (International Journal of Operations and Production Management, 1999:1190).

(b) Autonomous Maintenance

Autonomous Maintenance activities, one of the most distinctive features of TPM, involve operators in the routine maintenance and improvement of equipment (Bernstein, 2005:63).

One of the main arms of TPM is Autonomous Maintenance (AM), known as *Jitshu Hosen* in Japanese. The success of TPM, to a large extent, depends upon the success of AM. The three main objectives of AM, according to Nadarajah, Sambasivan and Yahya (2005:92), are:

- Establishing an orderly shop floor where any departure from normal conditions can be identified immediately,
- Fostering the development of operators as knowledgeable workers since most of the routine maintenance tasks are carried out by the operators themselves with assistance from maintenance department, and
- Maintaining the equipment in a "near new" condition.

In promoting TPM, everyone from top to bottom in the organisation must believe that it is feasible for operators to perform autonomous maintenance and that individuals should be responsible for their own equipment. In addition, each operator must be trained in the skills necessary to perform autonomous maintenance (Nakajima, 1988:73).

(c) Planned maintenance

- Planned Maintenance or scheduled maintenance includes breakdown, preventive and predictive maintenance. Planned Maintenance activities stress monitoring mean-time-between-failures (MTBF) data to specify the interval between activities in annual, monthly and weekly maintenance schedules (Bernstein, 2005:63). Planned Maintenance is led by maintenance personnel but with operator participation. It consists of regular intensive servicing carried out

periodically with the equipment stopped. It could also be regarded as ongoing equipment improvement aimed at eliminating failures and defects (Tsuchiya, 1991:143).

Whereas Autonomous Maintenance is deployed with operators in the leading role, Planned Maintenance, on the other hand, is the basic activity performed by maintenance specialists. The benefits that any division derives from its maintenance activities depend largely on the level of Planned Maintenance, which varies considerably (Tsuchiya, 1991:143). The aims of Planned Maintenance are as follows:

- To correct minor flaws and abnormalities (restore equipment to the ideal state and service areas that cannot be reached during daily maintenance).
- To perform periodic measurement and diagnosis (control accuracy)
- To exchange parts periodically (replace parts that show wear or deteriorate through friction or contact)
- To disassemble, inspect and overhaul periodically (rotating machinery, gearboxes)
- To implement improvements (increase access to hard-to-inspect places and prolong equipment life)
- To educate (train operators on set topics and encourage self-study by maintenance personnel)
- To perform inspection and improvement from quality maintenance analysis and identification charts

Planned Maintenance determines the most appropriate times to deal with minor flaws and abnormalities discovered while the equipment is running, to carry out regular disassembly and overhauls and to effect various improvements. These activities are undertaken chiefly by maintenance personnel but with operators also participating. Planned Maintenance consists of concrete action incorporating planned education which allows all participants to rotate the PDCA cycle and gain a great sense of satisfaction (Tsuchiya, 1991:144).

(d) Technical training

Technical training in equipment maintenance and operation identifies the specific knowledge, skills and management abilities people should have so that right training programmes can be designed to instill them (Bernstein, 2005:63).

According to Shirose (1992:138), the following skill-related conditions are absolutely necessary for successful TPM:

- Equipment operators should possess the training and skills to carry out autonomous maintenance and understand their own equipment
- Maintenance department staff should possess the training and skills to carry out maintenance and repairs and to smoothly implement preventive maintenance.

More specifically, equipment operators cannot clean and lubricate properly unless they know the tightness of the bolts as well as the structure, functions and inspection methods for each piece of equipment. And this cannot be merely theoretical knowledge – the operators must be skilled in applying it in cleaning and lubrication. In addition, maintenance staff needs to have the skills to do repairs like fitting or replacing keys and bearings. This is why skills training is so important for TPM activities (Shirose, 1992:139).

A company implementing TPM must invest in the training that will enable employees to manage their equipment properly. In addition to training maintenance techniques, operators must also sharpen their conventional operation skills (Nakajima, 1988:96).

(e) Early equipment management

Early equipment management aims to have products that are easy to make and equipment that is easy to use. It addresses equipment and process design, fabrication, test and startup management (Bernstein, 2005:63).

Early equipment management means minimising the time to achieve stable operation (no breakdowns and minimal defects) during the installation, test-run and handover (commissioning control) periods (Shirose, 1992:144). Naturally, to have equipment operating flawlessly at installation would be best, but when new equipment is

installed, problems often show up during test-running, commissioning and startup even though design, fabrication and installation appear to have gone smoothly (Nakajima, 1988:96). Engineering and maintenance engineers may have to make many improvements before normal operation can begin. Even then, startup period repairs, inspection, adjustment and the initial lubrication and cleaning needed to prevent deterioration and breakdown are often so difficult to carry out that the supervising engineers become thoroughly discouraged. As a result, inspection, lubrication and cleaning may be neglected, which needlessly prolongs equipment downtime for even minor breakdowns (Nakajima, 1988:97).

Early equipment management is performed mainly by production engineering and maintenance personnel as part of comprehensive approach to maintenance prevention (MP) and maintenance-free design. These goals are prompted through improvement activities at various stages: the equipment investment planning stage, design, fabrication, installation and test running, as well as commissioning (when normal operation with an actual flow of products has been established). Debugging (detecting and correcting errors and faults) is included in these activities (Nakajima, 1988:97). These activities aim at:

- Achieving the highest levels possible within the limits established at the equipment-investment planning stage;
- Reducing the period from design to stable operation;
- Processing through this period efficiently, with minimum labour and no working imbalance;
- Ensuring that the equipment designed is at the highest levels of reliability, maintainability, economical operability and safety.

By working together with engineers during commissioning to eliminate problems at the source and promoting activities within individual project teams, the engineering and maintenance staff can absorb and apply knowledge about Maintenance Prevention design (Nakajima, 1988:98).

(f) Quality Maintenance

Quality Maintenance activities build in quality by managing variability in quality characteristic by controlling the condition of equipment components that affect it (Bernstein, 2005:63).

Companies achieve quality not by checking results or screening out defects, but by ensuring that no defects are created by upstream processes. Quality Maintenance is a specific method for building in quality through processes and equipment (Suzuki, 1992:86).

An effective method is to perform P-M analysis on past quality problems and set the conditions based on the results. The parts of the plant that affect quality characteristics are normally called quality components. Quality Maintenance consists of preventing the creation of defects by maintaining the quality components at their set conditions and thereby guaranteeing the required quality (Suzuki, 1992:87).

In other words, manufacturing technology, plant engineering and operating expertise all ensure that the quality is built in through the process and combine to create a final product of high quality (Suzuki, 1992:90).

(g) Office TPM

Office TPM means that administrative and support departments must supply high-quality and timely information for TPM activities and must streamline the flow of information (Bernstein, 2005:63). Office TPM should be started after activating four other pillars of TPM (JH, Kaizen, QM, and PM). Office TPM must be followed to improve productivity and efficiency in the administrative functions and to identify and eliminate losses. This includes analysing processes and procedures towards increased office automation. Office TPM addresses twelve major losses (Venkatesh, 2007:19). They are:

- Processing loss
- Cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventory

- Communication loss
- Idle loss
- Set-up loss
- Accuracy loss
- Office equipment breakdown
- Communication channel breakdown, telephone and fax lines
- Time spent on retrieval of information
- Non-availability of correct on-line stock status
- Customer complaints due to logistics
- Expenses on emergency dispatches/purchases.

(h) Safety and environmental management

Safety and environmental management includes implementing accident prevention training, near-miss analysis and ways of preventing adverse environmental impacts (Bernstein, 2005:63).

In this area the focus is on creating a safe workplace and a surrounding area that is not damaged by the process or procedures. This pillar will play an active role in each of the other pillars on a regular basis (Venkatesh, 2007:21).

Target:

1. Zero accidents
2. Zero health damage
3. Zero fires.

A committee is constituted for this pillar, which comprises representative of officers as well as workers. The senior vice-president (Technical) heads the committee. Safety is a priority in the plant. The manager (Safety) looks after functions related to safety. To create awareness among employees various competitions like safety slogans, quizzes, drama and posters related to safety can be organised at regular intervals (Venkatesh, 2007:21).

2.4.3 Benefits of TPM

It has been established that TPM enables maintenance systems to be developed and operated effectively and integrates the activities of production and maintenance personnel. It brings a different approach to both operations and maintenance and encourages a change in attitude which benefits everyone in the company. It makes businesses more competitive, changes the working environment for the better, encourages and enhances people and, overall, transforms the way in which a company operates (Davis, 1995:54).

According to Davis (1995:58), TPM then addresses each aspect of the operation in the company as follows:

- The combination of production-led, autonomous maintenance activities, focused improvement projects and effective maintenance system will greatly reduce the number of machinery breakdowns.
- Through monitoring, plotting and analysing overall effectiveness information the significance of product changeover and adjustment time will be established quickly. The overall effectiveness information will help to prioritise and justify the need for and cost of changeover time reduction projects and will provide the impetus necessary to carry out such projects. Under the auspices of TPM changeover time reduction projects will be carried out and, if carried out in a structured way, reductions of at least 50 percent will be achieved.
- As a result of autonomous maintenance activities and improved maintenance system, the general condition of machinery will be improved. This will lead to an improvement in the quality of products and confidence of personnel in the consistency of the process. Also, where the overall effectiveness information can be used to identify problem areas and justify focused improvement projects such as process capability studies, these will improve the consistent quality of products.
- TPM activities will gradually rebuild employee morale and relationships. By improving not only machines but also the general working environment, factory level personnel will benefit and morale and enthusiasm will improve.

Communications will greatly improve as frank and honest “two-way” communications mechanisms are put in place through the TPM teams.

- Many TPM activities subtly bring together people from many levels of the company and from different departments. Once problems are being approached in a professional and structured way then the true situation and cause of problems can be clearly identified. TPM insists that a "no blame" culture is cultivated and, by working together, the traditional barriers between departments and levels within the company are gradually dismantled.
- Panic gradually becomes a thing of the past and personnel are taught new skills which are more geared to planning, analysing and improving rather than reacting. When people start to operate within a more controlled and organised environment they become determined not to allow the situation to revert to ‘panic mode’ again.
- The working environment becomes much cleaner, tidier and neater and standards of cleanliness and tidiness gradually increase. One very noticeable characteristic of any TPM factory is that it is very clean and tidy and this in itself will improve people’s morale and pride in the workplace

2.5 THE ERGONOMIC AND HUMAN FACTORS IN DESIGN FOR MAINTENANCE

During the process of designing a product, the designer will necessarily consider many factors which influence the concept, details or choice of materials for the product. Examples are cost factors, stress concentration factors, power factors and factors of safety. All these factors are simply important elements to be considered during the analysis of the design problem and the synthesis of its solution. They establish the envelope of physical or economic parameters within which the product must be designed if it is to perform its intended function (Hunter, 1992:37).

Quite commonly, however, designers, in their zeal to solve the often formidable physical and economic problems, forget that their wonderful invention is going to be used or operated by a mere mortal. The result is that some motor car seat belts chafe the driver’s

neck, some video cassette recorders defy their owners' efforts to programme them and some engine-driven power equipment makes so much noise that the operator suffers a hearing loss. Many other examples could be cited, but in each case the designer failed to pay enough attention to the limitations of the ultimate factor at the end of the line – the human factor (Hunter, 1992:37).

Ergonomics considers the ability of the user to perform a physical work. It focuses on the size of the force required to perform a particular movement and the distance through which that movement is carried out. It includes the effects of fatigue on the worker when repetitive operations are performed over a certain span of time (Hunter, 1992:38).

Human factors are generally defined as the study of humans and their interaction with products, environments and equipment in performing tasks and activities. The focus of human factors is on the application of knowledge about human capabilities, limitations and other characteristics to the human-machine systems. The general objective of human factors is to maximise human and system efficiency and health, safety, comfort and quality of life (Salvendy, 2006:32).

2.5.1 Design requirements or maintainability

Although the equipment operator or the user of a product will necessarily be given priority in human factors design efforts, sometime during its service life that equipment or product is probably going to need some maintenance or repair work. In many instances the type of work to be done and how often it is to be performed are spelled out in recommended maintenance procedures that accompany the product at the time of delivery. As an example, every purchaser of a new motor car receives a schedule of recommended maintenance in the owner's manual (Hunter, 1992:55).

While one of the worthwhile objectives of product designers is to reduce the amount of maintenance required, another obvious objective should be to make the performance of the known necessary tasks as simple and convenient as possible for the person who eventually has to do the job. Among them are several which can be applied (Hunter, 1992:55-59):

- Avoid the use of special tools.

- Make wear-out items replaceable as modules.
- Design adjustments to be mutually independent.
- Provide failure indications to make troubleshooting fast, simple, and easy.
- Check for proper accessibility to parts.
- Design for goofproof re-assembly (use non-interchangeable fittings, distinctive pin alignment pattern and colour codes).
- Use knobs for frequently made adjustments.
- Avoid stacking of components (the one that went bad is always on the bottom).
- Never provide a screwdriver adjustment which is not clearly visible during adjustment.
- All lubrication fittings and lubricant levels must be serviceable without disassembly.
- Minimise the number of types of fasteners.
- Provide captive fasteners where dropping or loss of the item may result in damage to equipment or danger to personnel.

Designers should provide the capability for rendering the equipment inoperative whenever maintenance workers have to get any portions of their bodies into a position where moving parts of the equipment could cause injury if the equipment were started accidentally. This is known as lockout provision. If the part of the equipment store is mechanical, electrical or fluid energy, provision must be made to neutralise these energy sources during maintenance work. This feature is known as the zero energy state. It is intended to prevent maintenance workers from being injured by falling weights, loaded springs which suddenly snap back, electric capacitors which shock workers by discharging when touched and sudden release of pressure from liquid or gas storage containers. Such design requirements are addressed by the National Safety Council and by OSHA (Hunter, 1992:59-60).

2.5.2 Workspace dimensions

One of the basic requirements for a suitable work environment is that the space provided for workers be large enough for them to perform the required task. This

obviously requires that the size, weight and motion capabilities of human operators be known (Hunter, 1992:71).

2.5.3 Employee wellness

Management's efforts should be directed at eliciting from employees the behaviour and performance that will best achieve the organisation's mission and objectives. Apart from attracting and appointing high quality staff and deploying strategies and practices that unlock the potential of employees, management may also need to show that they care for or look after their employees. In addition to the provision of remuneration and fringe benefits, it is important also to promote and maintain the overall general state of wellbeing of the organisation's employees. All things being equal, an employee who is generally well will usually perform better than one who is generally not well. The idea is thus to improve and maintain "employee wellness" (Swanepoel, 2003:541). As Matlala (1999:24) states: "Failure by organisations to adopt employee wellness into their culture will inevitably lead to the escalation of sickness and the deterioration of organisational performance".

Employee wellness refers to the employees' state of optimised social, physical and mental health and wellbeing. It entails a holistic approach to looking after the physical, psychological and social state of wellbeing of the employees of an organisation. The absolute minimum requirement in this respect is to provide a working environment that is safe and that complies with all legal requirements. Of course, taking good care of an organisation's employees goes beyond simply keeping within the requirements of the law. A much more constructive and proactive approach is required to elicit, enhance and maintain optimal states of wellness that are beneficial to both employees and the organisation (Swanepoel, 2003:541).

In more recent times, with the spiraling costs of medical care, as well as the growing realisation that absenteeism costs a lot of money and that labour productivity must be improved, management has been considering alternatives that may yield results superior to the reactive, minimum-legalistic approach (Swanepoel, 2003:547).

It has become increasingly common for managers to consider the potential benefits of a system focused on proactively promoting and maintaining the mental and physical wellbeing of employees rather than dealing with health and safety problems as they occur (Swanepoel, 2003:547).

2.5.4 The role of TPM

The goal of TPM is to effect fundamental improvement within a company by improving worker and equipment utilisation (Nakajima, 1988:54). If TPM is to be applied successfully within any company there is a need to take on board not only the practices and techniques described but also the philosophy which is the very essence of TPM. It represents a fundamentally different style of management and employee participation. It is harder to resolve the "soft" people issues than to apply the TPM practices and techniques and the people issues will, in most cases, take much more time and effort. The TPM philosophy contains the following elements (Davis, 1995:21):

- Team working
- Respect for people at all levels
- Motivation of people at all levels
- Participation and encouragement
- Positive leadership and support
- Opportunity for people to acquire and enhance skills and experience, and develop their full potential
- Continuous improvement, always striving to do better
- Recognition of effort and providing incentives

The operating companies of today have to respond to the ever-changing needs and demands of their business environment (Davis, 1995:6). A business does not usually have very much control over these external factors and therefore must be able to respond when any of them change. Within its own boundaries, however, a business does have control over the internal factors which govern how effectively it operates and its ability to respond to external changes (Davis, 1995:7). The internal factors include the following:

- People: the skills and expertise of the people employed by the business, their enthusiasm, flexibility and how effectively they are utilised (Davis, 1995:8).
- Culture: the prevailing culture within the company, people's attitudes and values, their relationships with colleagues and external parties. This is formed over many years and is rooted in the history of the business (Davis, 1995:8).

If workers become interested and involved in maintenance, they learn the basic principles and key points of their equipment. And as they develop their ability to maintain and improve their equipment, they experience a sense of accomplishment and satisfaction (Tsuchiya, 1991:7).

Operators should maintain and inspect their machines as well as operate them, and maintenance personnel should not just be specialists in their mechanical or electrical systems but should understand both disciplines. The current situation requires that as many people as possible be trained in maintenance and improvement skills. As people master skills and become involved in planning, measurement, judgment, execution and improvement, they will develop a sense of satisfaction and achievement (Tsuchiya, 1991:9).

Increased automation and unmanned production will not do away with the need for human labour – only operations have been automated; maintenance still depends heavily on human input. Automated and technologically advanced equipment, however, requires skills beyond the competence of the average maintenance supervisor or worker, and to use it effectively requires an appropriate maintenance organisation. TPM, which organises all employees from top management to production line workers, is a companywide equipment maintenance system that can support sophisticated production facilities (Nakajima, 1988:2).

The dual goal of TPM is zero breakdowns and zero defects. When breakdowns and defects are eliminated, equipment operation rates improve, costs are reduced, inventory can be minimised, and as a consequence, labour productivity increases (Nakajima, 1988:2).

A company's success depends increasingly on the knowledge, skills and motivation of its work force. Employee success depends increasingly on having opportunities to learn and to practise new skills. This can be fostered by empowerment and teamwork. Empowerment simply means giving people authority – to make decisions based on what they feel is right, have control over their work, take risks and learn from mistakes and promote change. For example, employees can make decisions that satisfy customers without a lot of bureaucratic hassles and barriers between levels are removed (Evans & Dean Jr, 2003:110).

Human factors engineers generally agree that the overall efficiency of the system is determined by optimising the performance of both the human and physical components (Salvendy, 2006:33).

2.6 QUALITY FACTORS

Total quality is a business-wide philosophy which is all about changing attitudes, working practices, values and the overall method of operation of the company. Its overall aim is to continuously improve the operating performance of the business, thus providing better customer service and increased profitability. In many companies Total Quality Management (TQM) is only 'skin deep', i.e. it has been a relatively high-level exercise involving glossy posters, flow charts and other documents, mainly undertaken as a public relations exercise for their customers (Davis, 1995:11).

A tour around the factory floor and a few 'off the record' discussions with factory personnel very soon show that the true philosophy behind TQM has not been applied. There has been a tendency to ignore activities aimed at improving the condition and performance of facilities altogether, especially at factory level (Davis, 1995:12).

The way in which TQM has been implemented in many businesses has tended not to address the 'real' people issues and the resulting TQM business may look impressive from outside but underneath many of the old attitudes, prejudices and values still remain (Davis, 1995:12).

A central principle of TQM is that mistakes may be made by people, but most of them are caused, or at least permitted, by faulty systems and processes. This means that the root cause of such mistakes can be identified and eliminated and repetition can be prevented by changing the process (International Journal of Operations and Production Management, 1999:1190).

There are three major mechanisms of prevention:

- Preventing mistakes (defects) from occurring (Mistake-proofing or Poka-Yoke);
- Where mistakes cannot be absolutely prevented, detecting them early to prevent them being passed down the value-added chain (Inspection at source or by the next operation);
- Where mistakes recur, stopping production until the process can be corrected, to prevent the production of more defects. (Stop in time).

2.6.1 Communication

Communications within the company is always an area which appears to need improvement and is usually part of a Total Quality initiative. The resulting 'improved' communications structure very often only supports one-way communications, i.e. the top-down communication of management information and intentions. It misses out what is the most important part of communicating, i.e. listening. Effective channels from bottom-up communication are so often neglected, but are equally as important as top-down mechanisms (Davis, 1995:12).

A point that should be considered regarding communication is that personnel at different levels of the business tend to have different business interest spans. Managing Directors or General Managers whose business interest span is usually measured in one to five years as a major part of their job is to plan ahead. The senior managers or executives of the business will also think in terms of years, probably one to three years, and their subordinates, the middle managers, will tend to be interested in months to a year. Line managers to supervisors will be concerned with weekly and monthly targets and do not often have the opportunity to think further ahead than this,

whereas factory floor personnel have an interest span of days to a few weeks (Davis, 1995:12).

This business interest span pyramid should have a bearing on the way in which plans and initiatives are communicated at different levels. If, for instance, a new Total Quality initiative is launched, the effects of which will not be seen at the factory floor level for months or years, then it will quickly lose credibility if it is communicated too early, i.e. more than weeks before anything tangible happens. By "singing the praises" of new innovation within the company to personnel who will see little or no effect in the short to medium term, the result is that they will only feel let down and the "failure" will only fuel the perception that management is incompetent and untrustworthy (Davis, 1995:13).

2.6.2 Continuous Improvement

Continuous improvement is part of the management of all systems and processes. Achieving the highest of performance requires a well-defined and well-executed approach to continuous improvement and learning. "Continuous improvement" refers to both incremental and "breakthrough" improvement. Improvement and learning need to be embedded in the way an organisation operates. This means they should be a regular part of daily work, seek to eliminate problems at source, and be driven by opportunities to do better as well as by problems that need to be corrected. Improvements may be of several types (Evans & Dean, 2003:18):

- Enhancing value to the customer through new and improved products and services;
- Improving productivity and operational performance through better work processes and reductions in errors, defects, and waste;
- Improving flexibility, responsiveness and cycle time performance.

TQM is mainly concerned with continuous improvement in all work, from high level strategic planning and decision-making, to detailed execution of work elements on the shop floor. It stems from the belief that mistakes can be avoided and defects can be prevented. It leads to continuously improving results in all aspects of work, as a

result of continuously improving capabilities, people, processes, technology and machine capabilities.

Continuous process improvement means accepting small, incremental gains as a step in the right direction towards Total Quality (Jablonski, 1991:5). Continuous improvement simply means never resting on one's laurels. Regardless of the product or service, it can always be improved. What may be "good enough" today will very soon be outdated, unusable, and old-fashioned (Haberer & Webb, 1994:3).

The improvement process is not a non-recurring event. Depending on the company's progress and results, it is important to continue with quality improvement activities. Continuous improvement is required if the company is to be successful. Experience shows that people find it stimulating to be involved in quality improvement activities (Sandholm, 1997:205).

2.6.3 Customer focus

The customer is the judge of quality. Understanding customer needs, both current and future, and keeping pace with changing markets requires effective strategies for listening to and learning from customers, measuring their satisfaction relative to competitors and building relationships. Customer needs – particularly differences among key customer groups – must be linked closely to an organisation's strategic planning, product design, process improvement and workforce training activities. A business can achieve success only by understanding and fulfilling the needs of customers (Evans & Dean Jr, 2003:16).

Customer-driven firms measure the factors that drive customer satisfaction. A company close to its customer knows what the customer wants, how the customer uses its products and anticipates the needs that customer may not even be able to express. It also continually develops new techniques to obtain customer feedback (Evans & Dean Jr, 2003:16).

A firm also must recognise that internal customers – the recipients of any work output, such as the next department in a manufacturing process or the order-picker

who receives instructions from an order entry clerk – are as important in assuring quality as are external customers who purchase the product. Failure to meet the needs of internal customer will likely affect external customers. Employees must view themselves as customers of some employees and suppliers to others. Employees who view themselves as both customer of and supplier to other employees understand how their work links to the final product. After all, the responsibility of any supplier is to understand and meet customer requirements in the most efficient and effective manner possible (Evans & Dean Jr, 2003:17).

2.6.4 Empowerment and teamwork

A company's success depends increasingly on the knowledge, skills, and motivation of its workforce. Employee success depends increasingly on having opportunities to learn and to practise new skills. This can be fostered by empowerment and teamwork. Empowerment simply means giving people authority – to make decisions based on what they feel is right, have control over their work, take risks and learn from mistakes and promote change; for example, employees can make decisions that satisfy customers without a lot of bureaucratic hassles and barriers between levels are removed. Empowerment requires, as the management philosophy of Wainwrigt Industries states, a sincere belief and trust in people (Evans & Dean Jr, 2003:23).

A team is a group of people that has been formed to work together in common, cooperative actions towards the achievement of an outcome and for the benefit of the group rather than for individual benefit. The goal of the team should be synergy, in other words, the sum of the individual efforts in the team is greater than the sum of the individual input (Bagraim, Cunningham, Potgieter & Viedge, 2007:132).

The effective management of people in teams can produce greater performance levels and greater organisational effectiveness. The advantages of implementing teamwork are: better performance, job satisfaction, increased collective commitment to organisational goals, peer pressure to perform, increased commitment to team performance, generation of more creative solutions to problems, reduction to cost and time overheads and decentralised decision-making (Bagraim, Cunningham, Potgieter & Viedge, 2007:134)..

2.6.5 Moving from control to prevention

The new approach to quality is to improve production processes so as to prevent defects. The key to staying competitive is to do it right the first time, on time, every time. If the underlying production processes can be improved so that there is very little chance of failing to meet the specifications, then there is a saving in the cost of inspection and scrap and reworks. Consequently, items can be produced more cheaply and the firm can stay competitive (Burrill & Ledolter, 1999:16).

Much better than relying on control is to monitor processes on an ongoing basis. This approach allows one to recognise at once when something has gone wrong and to take immediate corrective action to fix the problem (Burrill & Ledolter, 1999:16).

2.6.6 Poka-Yoke (Mistake-Proofing)

Poka-yoke refers to mistake-proofing (also error-proofing or fool-proofing). These are creative devices that make it nearly impossible for an operator to make an error (Liker, 2004:133). Poka-yoke is an approach for the mistake-proofing process using automatic devices or methods to avoid simple human error. The idea is to avoid repetitive tasks or actions that depend on vigilance or memory in order to free workers' time and minds to pursue more creative and value-adding activities (Evans & Dean Jr, 2003:110).

Poka-yoke is focused on two aspects: prediction or recognising that a defect is about to occur and providing a warning and detection, or recognising that a defect has occurred and stopping the process. Many applications of poka-yoke are deceptively simple, yet creative. Usually, they are inexpensive to implement. Many machines have limit switches connected to warning lights that tell the operator when parts are positioned improperly on the machine (Evans & Dean Jr, 2003:110).

The method is designed to initially compliment quality inspection and control within the workplace, as it is impractical to alter a complete quality system overnight. However, the ultimate goal of poka-yoke is to replace the need for quality inspection – the defects should highlight themselves. Systems are generally designed so that if the first operation is faulty then it will be impossible to start the next operation. This

is achieved through a combination of careful planning of the order in which operations are completed and good engineering innovation (Ross, 2003:116).

The beauty of the system is that components and processes are designed to alert the operator to poor quality without the need for the operator's involvement, with the result that inspection is not required on parts. If good parts are inspected, that is a waste of resources. Why inspect it if it is good? With poka-yoke devices in place, poor parts are automatically flagged, so operations can work away sure in the knowledge that they are producing what they should be producing (Ross, 2003:117).

Poka-yoke in industry has generally become to be accepted as preventing bad components from moving through the process line. However, there are a number of different areas that poke-yoke is used in. The main benefits of this system are obvious (Ross, 2003:117):

- Less scrap and rework
- Greater quality control
- Addressing of safety issues
- Protection of machinery.

Poka-yoke is a service process requires identifying when and where failures generally occur. Once a failure is identified, the source must be found. The final step is to prevent that mistake from occurring through source inspection, self-inspection, or sequential checks (Evans & Dean Jr, 2003:111).

Greater quality control is obtained through three main factors (Ross, 2003:154):

- The operator is responsible for the running of the cell, therefore it is up to him/her to ensure that quality is of a sufficiently high standard. This can be improved and made easier when Poka-yoke is also introduced, reducing the need for intensive quality inspection.
- The introduction of Work Standardisation details the number of components or time space between traditional quality checks, such as SPC, and will therefore act as a catalyst and reminder for quality.

- If one operation is producing faulty components, then this is generally picked up on the next operation. This leads to a much smaller number of faulty components passing through before they are noticed, as opposed to a full batch production run. The main benefit of this is that one operator is involved in a number of different operations, therefore s/he will have a greater understanding of the process as a whole rather than one small section without any idea of what has gone before or will come after.

From the perspective of total quality, creativity and innovation are needed to better respond to customer needs, particularly the "exciters/delighters" that customers cannot articulate, and to develop the products and services that will position an organisation strategically ahead of its competitors. They also are needed to support continuous improvement efforts, for example the poka-yoke devices and methods discussed in this chapter. Finally, an environment that fosters creativity and innovation can motivate employees more than any extrinsic reward. Thus creativity and innovation are instrumental in achieving the principle of total quality (Evans & Dean Jr, 2003:112).

The TQM organisation does not wait for the day that their product or service is eclipsed by the competition. They are working today on improvements that will be implemented long before their customers become dissatisfied (Haberer & Webb, 1994:3)

TPM is Total Quality aimed at improving the condition and performance of the facilities that the business uses to perform the operations process. It is total quality at the "sharp end", i.e. where processes are performed, value is added and the wealth is created for the business. Through the TPM teams, good and effective channels of communication are established and people at all levels within the company are given the opportunity to put forward their views and ideas. This is a very important issue for the business and if Total Quality fails to address this area then it will not succeed. Therefore it can be seen that TPM is an essential component of TQM (Davis, 1995:13).

2.7 SUMMARY

The literature study supports the fact that the purpose of measuring OEE is to drive improvement in the production process. For OEE to meet this goal it is crucial that people using OEE, or any measure for that matter, understand why they are making the measurement and what is going to happen with the information collected. The leadership must understand it, too, and clearly communicate their expectations and intentions to operators. If this very critical step is not taken, the measure could impair improvement effort instead of driving it (Bernstein, 2005:105).

If a company wants to practise "profitable TPM" and pursue optimal equipment effectiveness, the following two factors are crucial. First, accurate equipment operation records must be kept so that the appropriate management and control can be provided (with narrower targets); and second, a precise scale for measuring the equipment operating conditions must be devised (Nakajima, 1988:24).

In TPM, "individual improvements" are the activities companies carry out to improve their performance by thoroughly eliminating the Six Big Losses and maximising Overall Equipment Effectiveness (Nakajima, 1988:58).

It also revealed that operators play a key role in data collection and in ensuring daily cleaning through Autonomous Maintenance. Collecting and analysing OEE data is the basis of a systematic approach to reducing equipment-related losses. Therefore training plays a crucial part in ensuring that operators understand their piece of equipment so that they can collect the appropriate and correct data required for continuous improvement.

TQM is a management methodology, a way to run business, not a fad or some gimmick to spur productivity momentarily or to improve some special factor. In embracing TQM, management must substantially change the culture of the business so that TQM principles can be established. Once TQM is focused on the strategic aims for business success, the direction will be visible and known to all employees (Burrill & Ledolter, 1999:35).

In this chapter we have shown how comprehensive and important the field of employee wellness promotion and maintenance is. It was argued that a reactive approach to

employee health and safety is no longer applicable or sufficient. What is needed is a holistic and proactive approach to promoting and maintaining the complete wellbeing of an organisation's personnel – areas that have to be attended to professionally in order to ensure an environment where employees feel and know that they are being cared for – because they are such valuable resources (Swanepoel, 2003:585).

Chapter three will provide an overview of Ford Struandale Engine Plant with regard to Overall Equipment Effectiveness, availability, performance effectiveness, quality rate, the Six Big Losses and Ford Total Productive Maintenance.

CHAPTER THREE

FORD STRUANDALE ENGINE PLANT LITERATURE REVIEW

3.1 INTRODUCTION

In chapter two a literature summary was conducted in order to determine what has previously been written about OEE. The literature identified Six Big Losses as the key contributors to Overall Equipment Effectiveness and also highlighted ways of improving OEE by eliminating the Six Big Losses.

The purpose of this chapter is to introduce the current programmes and systems that Ford Struandale Engine Plant is using. This chapter will start with a brief background of the company and indicate future plans, will also discuss Ford Total Productive Maintenance, the ergonomic and human factors in design for maintenance, quality and a brief summary.

Ford has pioneered several innovative motor car manufacturing techniques since its inception. Ever since it began operations in 1903, Ford has been recognized as a manufacturing process innovator in the motor car industry. For instance, in 1907, Ford introduced the mass production system which produced cars of uniform quality and features in bulk and sold them at an affordable price to customers. In the mid 1990s, Ford restructured its manufacturing operations in its efforts to induce more flexibility and enhance the efficiency of its motor car production systems. The restructuring effort was known as Ford Production System (FPS).

By using lean manufacturing principles, Ford had significantly improved the quality of the motor cars it produced. Jim Padilla, Ford's group vice-president of Global Manufacturing said, "Ford is aggressively implementing lean manufacturing principles through the Ford Production System at all of its manufacturing operations. This is the key to success in an increasingly competitive vehicle market (http://www.icmrindia.org/casestudies/catalogue/Operations/Ford%20Production%20System-Operations%20Management%20Case%20Study.htm).

Lean manufacturing aimed at bringing together human, material and mechanical resources at the right time and place to accomplish a task. It strove to eliminate every kind of waste including wastage of time, labour, scrap material and defective parts. There were several instances in which the company achieved massive productivity improvements through lean manufacturing techniques (http://www.icmrindia.org/casestudies/catalogue/Operations/Ford%20Production%20System-Operations%20Management%20Case%20Study.htm).

Apart from using advanced technologies to help reduce waste, FPS emphasised the human aspects as well. It required its employees to form teams called work groups and empowered managers to take work decisions without wasting time. Ford implemented the FPS in its plants across the world and realised improved productivity levels and financial performance (http://www.icmrindia.org/casestudies/catalogue/Operations/Ford%20Production%20System-Operations%20Management%20Case%20Study.htm).

The Ford Engine Plant in Port Elizabeth goes a long way in the Ford Company's history. The Struandale Engine Plant was set up in 1924 and was the 16th Ford plant outside North America. At present, under the auspices of Ford Motor Company of Southern Africa (FMCSA), the Ford Engine plant has continued to survive and grow relentlessly within FMCSA's global operations (http://www.aidc.co.za/index.php?pid=269&ct=1&dc=6).

In January 2008 Ford Motor Company announced plans to invest more than R1.5 billion to expand operations for the production of Ford's next-generation compact pickup truck and the PUMA diesel engine. The investment will commence in 2009 and be split between its assembly plant in Silverton, Pretoria and engine facility in Struandale, Port Elizabeth. Production of the new diesel engine is scheduled to begin in 2010, followed by production of the new pickup in 2011 (http://www.autoblog.com/2008/01/31/ford-to-invest-209m-in-south-africa-for-new-ranger-pickup/).

The Engine Plant in Port Elizabeth currently produces the Ford 1.3-litre and 1.6-litre RoCam engines, which it exports to Ford plants in India and Europe. In addition, machined components are exported to China and India. Designed by Ford in Cologne (Germany) to be a true world engine, this state-of-the-art power plant boasts exceptional power and

torque, low operating costs, outstanding reliability and durability – as well as remarkable economy. The engines are used in domestic production and exported. Average engine production is 240,000 units per annum (http://www.ford.co.za/servlet/ContentServer?cid=1178818935468&pagename=Page&c=DFYPage).

Ford Production Systems (FPS), the automaker's lean production system, "provides a framework of actions and behaviours that support lean manufacturing". On a corporate level, the Ford Total Productive Maintenance (FTPM) office is a department within the Ford Production System office (http://www.vo.ford.com/departments/quality/fps_europe /training/fps/fps_measurables06.html).

3.2 FORD TOTAL PRODUCTIVE MAINTENANCE

The objective of Ford Total Productive Maintenance **(**FTPM) is to maximise the overall effectiveness of the plant facilities, equipment, processes and tooling through the focused efforts of Small Group Activities directed at elimination of the Seven Major Losses (Equipment Breakdowns, Setup and Adjustments, Idling and Minor Stoppages, Reduced Speed, Startup Losses, Quality Defects in Process and Tooling Losses) associated with manufacturing equipment. The five necessary Pillars for sustaining FTPM performance are 1) Work Groups (separate FPS Element), 2) Training (separate FPS Element), 3) Planned Maintenance, 4) Improving Equipment Effectiveness and 5) Early Equipment Management (Section 4.5 of Manufacturing Engineering).

FTPM in Ford terms is defined as self-directed cross-functional work groups, working together to improve the overall effectiveness of the plant facilities, equipment, processes and tooling through the focused efforts in the elimination of the "seven major losses" associated with manufacturing equipment (http://hub.fmcsa.Ford.com/pe/FORD/ FordStructure/ASPPages/FTPMpackages.asp).

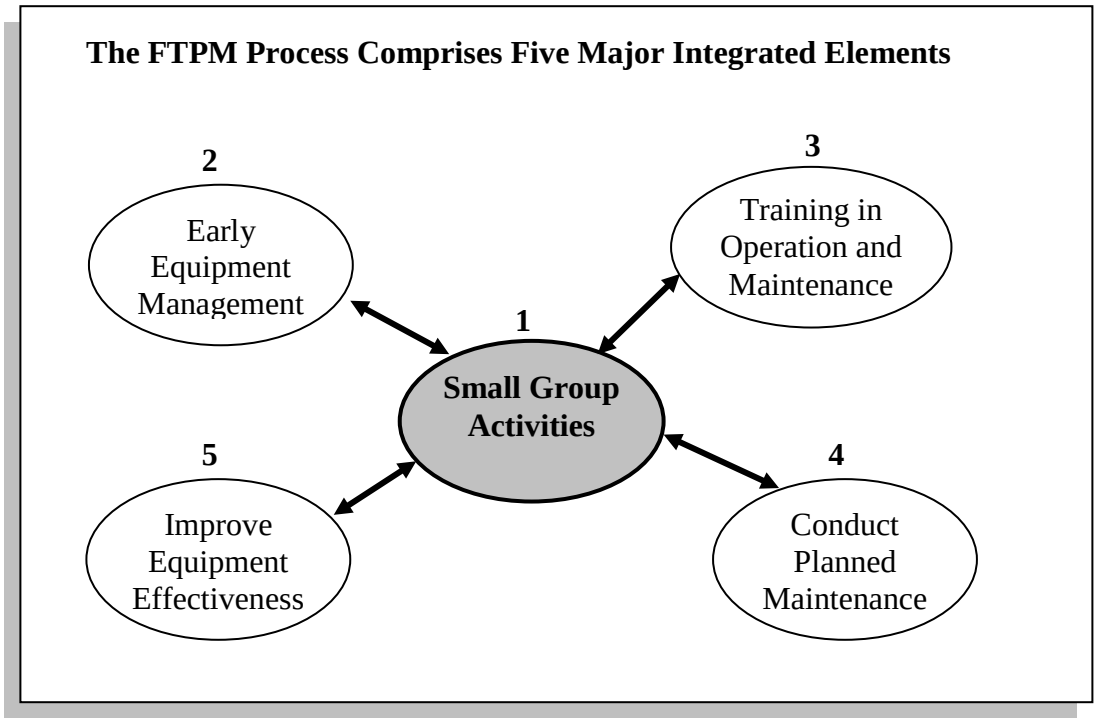
The FTPM steering committee, co-chaired by FTPM coordinator and FTPM manager, meets monthly to ensure that TPM principles are adhered to and that FTPM is delivering results. Ford Struandale Engine Plant utilises FTPM to ensure equipment reliability and to

ensure equipment uptime. It comprises five major integrated elements as indicated in figure 3.1. All the management reports will be for the block machining line because the focus group recommendations will be sampled on blockline then be spread to the whole plant.

3.2.1 Five major integrated elements of FTPM

Table 3.1 below explains the five major integrated elements of FTPM.

Fig 3.1: FTPM five major integrated elements



Source: http://hub.fmcsa.Ford.com/pe/FORD/FordStructure/ASPPages/FTPMpackages.asp

(a) Small Group Activities

The first element - Small Group Activities (SGA) - is the element that provides the necessary link between the other elements. Once the Small Group Activities are functioning, they will provide improvements and information to the other elements. Small Group Activities include measuring and eliminating deterioration, ensuring that equipment is kept at its ideal level of operation and elimination of problems that affect safety, quality and productivity.

Like teams, small groups are cross-functional. They draw on experts from the centralised departments as needed. The FTPM Coordinator attends small group meetings, helps collect and analyse data, and coaches groups along the improvement process in addition to gathering and reporting plant-wide measures to management and the FTPM steering committee. The coordinator meets weekly with the maintenance supervisors to discuss preventive maintenance (PM), review oil usage and losses and work on refining the PM tasks to reduce costs.

(b) Early Equipment Management

The second major element of FTPM is Early Equipment Management. This is a process that minimises life cycle costs of new equipment. Early Equipment Management prevents the repetition of mistakes on the machines and equipment by providing feedback from small group activities of things gone right and things gone wrong.

FTPM Small Group Activities will collect the data necessary to assist engineers in developing improvements and modifications. Reliability and Maintainability (R&M) is a major part of early equipment management and requires that detailed data is captured in order to calculate true life cycle costs and Mean Time to Repair and Mean Time between Failures (MTTR/MTBF.

(c) Training in Operation and Maintenance

The third major element of FTPM is Training in Operation and Maintenance. The goal of FTPM training is fundamental and provides the specific skill improvements required by each employee. There are other types of training offered, such as Team Building, Reliability & Maintainability and Team Oriented Problem Solving (TOPS). Small Group Activities includes such topics as:

- Seven steps for SGA
- Visual inspection techniques
- Data collection
- An understanding of lubrication, hydraulics/pneumatics, fasteners and electrical/electronics.

- Enabling the operators to identify abnormal conditions on their equipment that may lead to equipment failure

In addition, training for skilled trades includes such topics as:

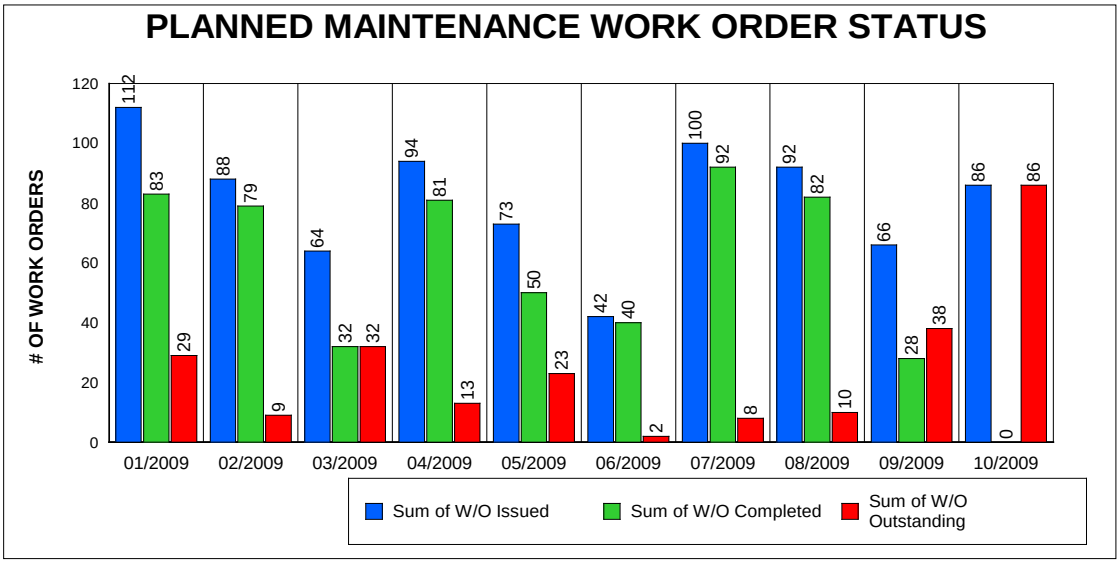
- Preventive maintenance techniques
- Vibration analysis
- Infrared
- Reliability and Maintainability (R&M)

(d) Conduct Planned Maintenance

The fourth major element of FTPM is Conduct Planned Maintenance**.** FTPM calls for the implementation of procedures for skilled trades to perform more preventive and predictive maintenance. FTPM uses Preventive Maintenance Excellence and Q1 as building blocks in terms of skilled trades working and cooperating with the Small Groups. With FTPM, skilled trade personnel will concentrate their efforts on work requiring an advanced level of skill such a predictive maintenance.

In addition to an increased number of the planned maintenance activities, the skilled trades will act as coaches to the job setters and operators to expand their understanding of the equipment.

Fig 3.2: Planned maintenance completion versus completion for block machining line



Source: W:\GROUP\PROD\!Shutdown Maintenance plans\2009 TEM & Maintenance Measurables\PM Completion\PM Completion (By line)

Also, the skilled trades act as technical resources to engineers to improve the reliability and maintainability of equipment and other maintenance technology advancements.

The data shown above on figure 3.2 indicate that the blockline machining line does not stick with the scheduled maintenance and each month there are outstanding planned maintenance (PM's) schedules. This could cause some unplanned downtimes as the machines are not maintained as planned.

(e). Improve Equipment Effectiveness

The measurement of Improved Equipment Effectiveness (OEE) is a product of three factors and the fifth major element of FTPM (http://www.fps.ford.com/learningeventslearningbew.html).

Availability is the amount of the time when equipment was needed to be run that it actually was able to be run.

This factor can be improved by the small groups running the equipment properly, taking care of minor abnormalities while they are still minor, doing planned maintenance and by reducing the time necessary for setup and adjusting activities including tool changes (http://www.fps.ford.com/learningeventslearningbew.html).

Annexure C indicates the availability versus downtime. The machine availability has been flat and the downtime is not improving: in some weeks it is actually getting worse. As shown in weeks 32 to 35, the trend is consistently deteriorating.

Performance Efficiency is a factor that measures how well the machine is running when it is available. Running at less than optimum cycle time has a major impact on this factor as does a "blocked and/or starved" process. The small group can have a major impact in this area by recording all line stoppage and minor downtimes that are frequently overlooked (http://www.fps.ford.com/learningeventslearningbew.html).

Annexure D indicates the performance efficiency of blockline machining line. From week one to week 40 the line has never reached its 70 percent target.

Quality Rate is basically first run capacity or first run quality. It is the number of good parts minus defective parts produced without spending non-value added labour (defective parts comprise scrap and re-worked parts, including those used to set up the line) (http://www.fps.ford.com/learningeventslearningbew.html).

Annexure E indicates the quality rate of blockline machining line. Assembly returns have improved from five percent in January to less than one percent in May, then zero returns in June till September. The average of 1.08% for 2009 to date is better than the 1.14% of 2008.

The machine scrap has been fluctuating and the 15% increase in June is the worst. The machining scrap has reached an average of 3.15% in 2009, worse than the 2.1% in 2008. The machining rejects have increased from 1.84% 2008 to 4.38% in 2009 to date. In June machining rejects reached an all-time high of a 30% increase, while the rest of the months have been 10% or lower.

These three factors which comprise the Overall Equipment Effectiveness (OEE) all have an effect on how well the equipment and processes perform to their ideal design levels. The value is in focusing on these factors to locate waste (http://www.fps.ford.com/learningeventslearningbew.html).

Improving any one of these three components should improve the following:

- Quality
- Productivity
- Lower cost
- Customer satisfaction
- Job security
- Survival

In FTPM, Overall Equipment Effectiveness (OEE) is used to measure equipment losses as indicated in figure 3.2.

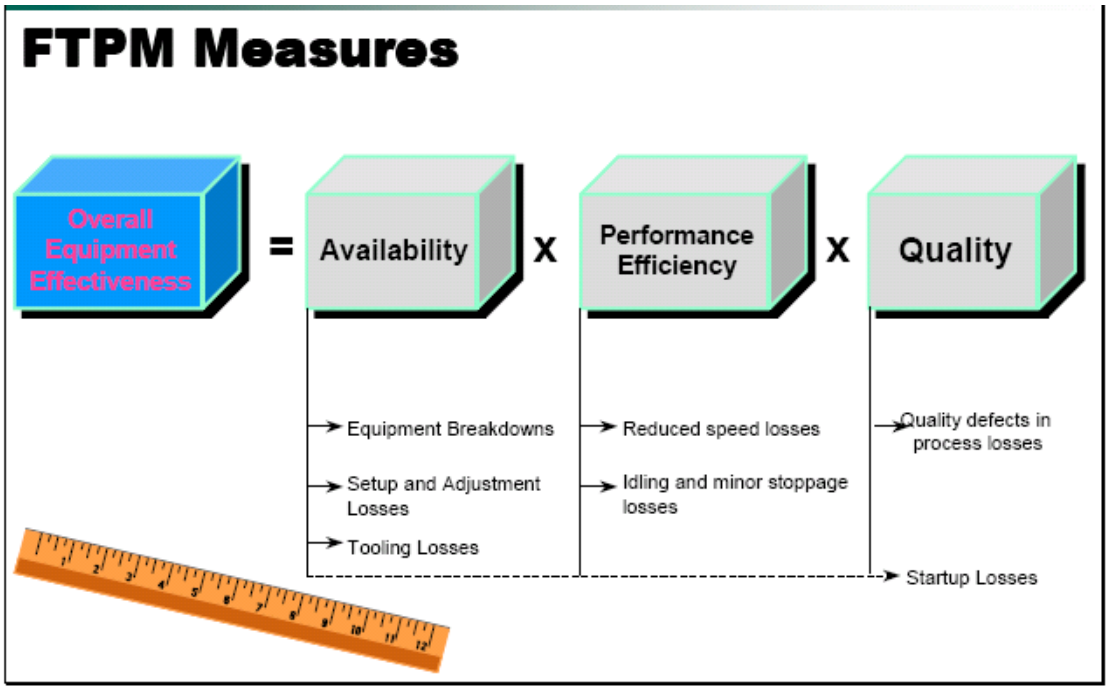
OEE formula, **OEE = Availability x Performance Efficiency x Quality Rate.**

First, availability is the time the machine is expected to run or total time on the job, less planned unmanned downtimes, such as lunch and breaks. From this total time, unplanned downtime is deducted, such as:

- Breakdowns
- Setup and adjustment losses
- Tooling losses

Effectively, availability is the percent of time the machine or process ran while it was manned.

Fig 3.3: FTPM Measures



Source: http://hub.fmcsa.Ford.com/pe/FORD/FordStructure/ASPPages/FTPMpackages.asp

The second factor in OEE is Performance Efficiency or "how close to design rate the machine ran when it was available". To increase performance efficiency:

- Reduce equipment ideal time

- Reduce minor equipment stoppage
- Run equipment at the most optimum speed

Performance efficiency is adversely affected by idling and minor stoppages and reduced speed losses.

Idling and minor stoppages are these small irritating problems that can easily be corrected, such as equipment “Blocked” or “Starved” for parts. Small problems are frequently overlooked but add up to considerable downtime during a shift. Once these losses have been identified and quantified, they should be part of the availability calculation.

The last factor is the quality rate, which indicates the amount of defects or parts run through the machine or process with non-value added labour. Quality rate is affected by:

- Quality defects
- Rework
- Start-up losses

Defects in process are scrap and re-worked parts. Any part that did not run through the machine or process without “non-value added labour” is considered a defect by FTPM.

Start-up loses are the kind of losses that occur after a shift change, weekend or holiday shut down when the equipment just will not run a quality part.

Any parts that are scrapped due to set up and “tuning” the line are counted as part of the quality start-up losses. The goal must be zero parts lost at any changeover start up. Many times these losses are overlooked as “it’s always been that way,” but to be a Best-In-Class manufacture, they must be corrected. The Big Losses are used to calculate an OEE and to provide a focal point for improvement.

3.3 THE ERGONOMIC AND HUMAN FACTORS IN DESIGN FOR MAINTENANCE

3.3.1 Risk Assessments

This element involves the requirement to have a system which systematically reviews the hazards and the appropriate control measures for each activity, reducing the risk by various means to the lowest reasonably practicable level. These assessments should then be used as a training aid for employees to make them aware of the residual risks associated with their jobs and the related control measures (http://www.ohs.ford.com/sharp/sharpindex.htm).

3.3.2 Accident / Incident / Illness Investigation and Analysis

A system should be in place to investigate accidents /incidents in order to determine root cause. The process should include injury accidents, near misses and property damage. The approach should then determine what action is required to prevent reoccurrence. The system should also be able to communicate best practice on corrective actions on occurrences (http://www.ohs.ford.com/sharp/sharpindex.htm).

3.3.3 Emergency Preparedness and Work Permits

The objective of this element is to ensure that a general emergency plan exists based on the need of the facility. General procedures and scenarios specific to operations must be planned and documented, with those involved trained and prepared. The process includes evacuations, clear responsibilities, communications with other parties and the resumption of production after a situation (http://www.ohs.ford.com/ sharp/sharpindex.htm).

The rules and work permits element requires a system to cover the enacting of rules and formalised permits whilst conducting specific activities. These rules and permits may relate to general work and safety regulations or relate to specialised activities such as entry to confined spaces or hot work permits (http://www.ohs.ford.com/ sharp/sharpindex.htm).

3.3.4 Personal Protective Equipment and Industrial Hygiene Controls

The use of such equipment is determined based on an examination and analysis of the work to be carried out based on risk assessment techniques. The element should essentially cover the requirements to identify the need and suitability of the equipment and cover the training of employees in its use. The process should include provision for ensuring that all personnel have the appropriate PPE required (http://www.ohs.ford.com/sharp/sharpindex.htm).

Industrial Hygiene anticipates, recognises, evaluates and controls hazards of a chemical, biological or physical nature. In the case of new or modified hazardous substances or processes an assessment should be made prior to use in a plant. The element includes requirements on investigations into workplace hygiene, logging of data during monitoring, publishing of test results and reports as well as recommendations of required improvements or modifications (http://www.ohs.ford.com/sharp/sharpindex.htm).

3.3.5 Clinical Operations and Employee wellness

The objective of Clinical Operations is to provide health diagnostics to prevent worker injuries and illness and provide medical care, treatment and rehabilitation to minimise employee injuries and illness. The element comprises topics that cover such factors as medical administration, facilities and equipment, health care systems, communication and employee assistance (http://www.ohs.ford.com/sharp/ sharpindex.htm).

The management and employee representative bodies of FMCSA demonstrate their concern for the emotional and social well-being of their employees / members and their dependants through the Employee Assistance Programme (EAP), as a means of ensuring the continued viability of the company.

The primary function of the EAP is the prevention and treatment of psychosocial problems. The EAP provides assistance with work-life balance issues, marital and family distress, emotional difficulties, financial constraints, substance abuse, stress and other personal problems which can all have a negative impact on job satisfaction,

as well as the efficiency and quality of work rendered by employees employed by FMCSA.

3.3.6 General Promotion

The General Promotion element is designed to strengthen and reinforce the attitudes of employees towards health and safety and risk management. Employees should be made aware of various topics in a number of ways in order to promote safety. These may include company safety notice boards, safety bulletins, a safety creed, topical articles or rewarding and promoting positive behaviour (http://www.ohs.ford.com/ sharp/sharpindex.htm).

3.3.7 Ergonomics

The purpose of the ergonomics element is to ensure a formal system to design or improve jobs to fit the capabilities of the employees. The element requires that there is a system implemented to determine concerns or problems and deal with concerns that have been raised in a formal manner. Appropriate ergonomic solutions should then be sought and implemented. Additionally these should be circulated on an appropriate system as best practice solutions. Training of key personnel is also an essential part of this element (http://www.ohs.ford.com/sharp/sharpindex.htm).

3.3.8 Compliance

Compliance relates to identifying and demonstrating company systems or procedures that ensure that certain key activities are carried out in a safe manner and that the company is complying with all its statutory requirements. Generally these relate to high-risk processes such as confined space working, working at height and loading and unloading areas for MP&L activities. The ability to be able to lockout equipment and a process for doing this lockout is also a key feature of the element; as is control of powered material handling vehicles and pedestrian safety initiatives (http://www.ohs.ford.com/sharp/sharpindex.htm).

3.3.9 Energy Control and Power Lockout (ECPL)

The purpose of ECPL is to establish workplace design standards and work practices that will prevent employee injuries and other incidents due to the release of

uncontrolled energy or unexpected motion of parts or materials in powered machines, tools, and equipment. "Whenever you have a need to place any part of your body in a position on or near machines or equipment where unexpected movement, release of stored energy, energising of electrical systems, or the flow of gases, fluids or other materials could have potential to injure the worker, then the worker has the RESPONSIBILITY and the AUTHORITY to correctly apply ECPL procedures and shall be held ACCOUNTABLE for that correct application" (http://www.ohs.ford.com/sharp/sharpindex.htm). Before employees put any part of their bodies in danger inside or near a machine, they must first isolate and lockout the energies (http://www.ohs.ford.com/sharp/sharpindex.htm).

3.4 QUALITY

The principle of quality at Ford Motor Company is far more than a mere checklist undertaken as part of the manufacturing process; it is a deeply rooted internal culture and a way of life, creating ongoing consciousness of commitment in the life of every employee. Ford Motor Company's ethos of quality is founded on the principle of *Kaizen* - a Japanese term referring to a process of continuous and never-ending improvement. It is a democratic philosophy, since it fully recognises the far-reaching potential value of the input rendered by even the most junior employee. Little wonder then that *Kaizen* is epitomised in all endeavours embarked upon by Ford Motor Company and all its employees (http://www.Ford.co.za/servlet/ContentServer?cid=1178818935395&pagename=Page&c=DFYPage).

Great people, using great technology, creating great things: This is the principle of victory found at the heart of the way Ford Motor Company does business (http://www.Ford.co.za/servlet/ContentServer?cid=1178818935395&pagename=Page&c=DFYPage).

Advanced procedures and technology alone would mean little, were it not for the commitment of the people utilising it. Ford Motor Company's operators therefore are highly trained and multi-skilled individuals. Ongoing training contributes vastly to the job enrichment of these employees, effecting in practice the company's vision to be Southern Africa's leading automotive company.

The work groups have the authority to stop the process when they see a defective process and fix it. The in-station process control also encourages continuous improvement as operators pick up problems early as they come out of their operations, before they go to the next operation. This will eventually lead to improvement.

3.4.1 Team structure

A cross-functional team must be formed and a certified facilitator assigned to each manufacturing facility or each new engineering programme. The team consists of product, process, manufacturing, supplier and customer members, on an as-required basis. Team size varies with the need for both adequate knowledge and good manageability. The team-meeting schedule should also be established (Dynamic Control Planning: WI 15-03-42).

3.4.2 Preventive actions

The FMCSA Engine Plant utilises formal Quality Planning Systems in order to formulate defect prevention systems. Quality planning systems are detailed in Procedures 16.02.02.

Information utilised to formulate preventative actions consists of, but is not limited to, the following:

- FMEA's
- Customer returns analysis
- Audit results
- Quality records

On an ongoing basis SPC is utilised as a preventative action. SPC systems are detailed in Procedure 16.02.20.

3.4.3 Corrective actions

The Engine Plant utilises two systems of trouble shooting and / or implementing corrective actions. Effective strategies for improvement depend upon whether the

variation is due to (corrective and preventative actions ISO 9000:2000 Section 8.5.2 (QS 9000 Sub Section 4.14)):

COMMON CAUSES	SPECIAL CAUSES
Pursue variability reduction, work simplification and/or other systematic process improvements.	Ask "What changed?", conduct "is/is not" analysis, and look for locally controllable causes.
↓	↓
PROCESS IMPROVEMENT	G8D

3.4.4 Process Improvement

This process is part of the culture at FMCSA Engine Plant. Static or worsening trends indicated by SPC Charts, Warranty Reports and Quality Trend Charts are investigated on a continual basis (corrective and preventative actions ISO 9000:2000 Section 8.5.2 (QS 9000 Sub Section 4.14)).

3.4.5 G8D

This process comes into effect when special causes are encountered in "process improvement" actions. Eight disciplined steps have been identified to promote an effective team-orientated problem-solving approach. The eight disciplined steps are stated below (corrective and preventative actions ISO 9000:2000 Section 8.5.2 (QS 9000 Sub Section 4.14)):

- Use team approach
- Describe the problem
- Define and verify root causes
- Verify corrective actions
- Implement permanent corrective action
- Prevent recurrence
- Congratulate the team

3.4.6 Design of experiments

Design of experiments will be utilised to improve processes where appropriate.

3.4.7 Issues Resolution

- The issue will be reported in the team's morning meeting. The Work Group consisting of a cross-functional team i.e. members, team leaders, foreman, maintenance personnel, process personnel and others will attempt to resolve the issue.
- If unresolved, the issue will be placed on the team's Concerns Corrective Action Report (CCAR) and priority and responsibility assigned to the problem.
- If still unresolved, the issue will be raised in the weekly presentation meeting. Communication to support persons can also be done via e-mail.
- The Area Manager will assist in resolving the problem, or failing to do so, will address it in the weekly In-station Process Control (ISPC)/Natural Work Group meeting (NWG).

3.4.8 Suppliers-customers links

Ford utilises the Supplier Engagement manual which is intended to define the internal Ford process for working with the supply base to launch quality parts within the Global Product Development System (GPDS). The GPDS Supplier Engagement strategy is first and foremost a cross-functional process that recognises supplier success as a function of the combined talents and input of many disciplines within Ford Motor Company (http://www.purchasing.Ford.com/prch_sta/index.htm).

The process is governed by the following principles:

- Supplier launch success is a cross-functional, shared responsibility.
- Ford cross-functional teams will work proactively with the highest leverage suppliers on a programme.
- Supplier Engagement will begin early in a programme – immediately after sourcing.
- Ford cross-functional teams will visit the key supplier manufacturing facility a minimum of four (4) times.

- The teams will provide the supplier with a single Ford voice on key launch matters.
- Team engagement will continue until the supplier has successfully completed all Production Part Approval Process (PPAP) requirements and fully met all programme ramp-up volumes.
- Ford will implement the supplier engagement process consistently on a global basis in alignment with the global makeup of the supply base.

The GPDS Supplier Engagement process describes a disciplined set of activities performed throughout a GPDS programme to ensure that critical parts delivered by Ford's supplier partners achieve the desired quality and capacity levels at Job #1. Working under the principle that supplier success is a shared responsibility among the different Ford organisations, the process is focused around a core cross-functional team made up of representatives from Ford PD, buyers, STA, MP&L and the supplier. This team will form shortly after sourcing and continue working together through successful completion of component PPAP (http://www.purchasing.Ford.com/prch_sta/index.htm).

The roles and responsibilities within this process are structured around ownership of the key elements of the industry standard Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP). APQP and PPAP are existing Ford processes and are both fundamental building blocks of GPDS (http://www.purchasing.Ford.com/prch_sta/index.htm).

The Supplier APQP/PPAP Readiness Assessment (Schedule A) is a structured method for defining and executing the actions necessary to ensure a product satisfies the customer. The goal of APQP/PPAP Readiness is to facilitate communication between all persons and activities involved in a programme and to ensure that all required steps are completed on time, with a high quality-of-event, at acceptable cost and quality levels (http://www.purchasing.Ford.com/prch_sta/index.htm).

APQP is the tool by which external suppliers perform Advanced Product Quality Planning (APQP) in accordance with the Ford Customer Specific Requirements. Successful implementation and use of Schedule A will ultimately prepare external suppliers for successful completion of the Production Part Approval Process (PPAP). APQP/PPAP Readiness Assessment reporting is a requirement for all external suppliers to Ford Motor Company (http://www.purchasing.Ford.com/prch_sta/index.htm).

Ford also engages with suppliers through Ford Warranty Reduction Programme ("WRP"). It is an incentive programme. It is designed to encourage cooperation between Ford and the suppliers to help reduce costs incurred by Ford Motor Company, its subsidiaries and certain of its affiliates (collectively, "Ford Companies") under new-vehicle warranties relating to goods supplied by the supplier that are covered under the WRP (http://www.purchasing.Ford.com/prch_sta/index.htm).

The changes in these warranty costs are generally measured by comparing the warranty cost-per-unit CPU of the Goods used on the model year of the vehicle line being evaluated with a specified baseline, which is either:

- the warranty CPU of the goods (or similar goods) on the prior model year of the vehicle line; or,
- an agreed fixed warranty CPU.

The whole process of supplier-customer engagement is controlled and monitored through Supplier Technical Assistance, which is well-known as STA, with a slogan "Leadership in the selection and development of Ford's global supply base to provide the highest quality and manufacturing capability to achieve word class customer satisfaction and safety" (http://www.purchasing.Ford.com/prch_sta/index.htm).

This was also made possible by the fact that when Ford Struandale Engine Plant started producing the RoCam engine in Port Elizabeth, it went to great lengths to establish local manufacturing of components, even getting new factories started when current factories could not make what is required. The investment was a great benefit

to the local economy and enabled Ford to get their supplies on a regular and reliable basis.

Currently Ford shares their best practices with the suppliers, even training suppliers in problem-solving techniques and Ford processes like G8D, Manage the Change (MTC) and APQP (http://www.purchasing.Ford.com/prch_sta/index.htm).

This vision supported by the Kaizen philosophy is paying dividends such as Ford Motor Company's attainment of the SA Bureau of Standards' ISO 9001 Award, and the Ford Motor Company's Q1 Quality Award which recognises the company's extreme levels of excellence and its advanced systems, designed for continuous improvement in meeting customer needs and expectations (http://www.at.ford.com/news/cn/Pages/FordengineplantinSouthAfricagetsworld-classstampforqualitymanagement.aspx).

The Ford Motor Company of Southern Africa (FMCSA) Engine Plant in Struandale has achieved a significant milestone by becoming one of the first plants in South Africa to attain the latest ISO 9001:2008 Quality Management System certification (http://www.at.ford.com/news/cn/Pages/FordengineplantinSouthAfricagetsworld-classstampforqualitymanagement.aspx).

"We perform regular internal audits throughout this process in order to ensure compliance with the ISO standard," explained Pedro Adams, Quality Manager, Struandale Engine Plant. He further explained, "Although it was not a requirement of ISO 9001:2008, we used APQP methodology to conduct contract reviews and found it to be highly effective. In addition, the process conformation methodology being introduced to the plant was recognised as an excellent improvement project, which allows us to continually strive for even higher standards of quality" (http://www.at.ford.com/news/cn/Pages/FordengineplantinSouthAfricagetsworld-classstampforqualitymanagement.aspx).

Ford Struandale Engine Plant has achieved the highest rating during the June 2009 Powertrain QOS audit by Lee Scott (Ford Europe PTO Quality Office). According to Lee, the plant has demonstrated great improvements and has consequently achieved a level 8 (top level) during the assessment. Now the Engine Plant is ranked number three just, one point behind number two in global Ford (http://www.at.ford.com/news/cn/Pages/Engineplantgetstopscoreforquality.aspx).

Quality Operating System (QOS) is a systematic, disciplined approach that uses standardised tools and practices to manage business and achieve ever-increasing levels of customer satisfaction. It is a collection of tools and methods used to continuously improve a company's product and services with the goal of customer satisfaction (http://www.purchasing.Ford.com/prch_sta/index.htm).

According to Wallace Yearwood, Plant Manager at Struandale Engine Plant, "It also gives the plant a level of confidence in its ability to operate at the highest international standards, which is vital for our success, especially considering that the majority of our business and our potential for future growth are export-driven," he concluded (http://www.at.ford.com/news/cn/Pages/Engineplantgetstopscoreforquality .aspx).

3.5 SUMMARY

Lean manufacturing is a step-by-step process, mainly implemented on a continuous basis. Ford Struandale Engine Plant has implemented most of the lean manufacturing tools through its FPS production system.

The objective of Ford Total Productive Maintenance **(**FTPM) is to maximise the overall effectiveness of the plant facilities, equipment, processes and tooling through the focused efforts of Small Group Activities directed at elimination of the Seven Major Losses (Equipment Breakdowns, Setup and Adjustments, Idling and Minor Stoppages, Reduced Speed, Startup Losses, Quality Defects in Process and Tooling Losses) associated with manufacturing equipment.

Ford utilises the Supplier Engagement manual which is intended to define the internal Ford process for working with the supply base to launch quality parts. APQP is the tool by which external suppliers perform Advanced Product Quality Planning (APQP) in accordance with the Ford Customer Specific requirements. Successful implementation and use of Schedule A will ultimately prepare external suppliers for successful completion of the Production Part Approval Process (PPAP). APQP/PPAP Readiness Assessment reporting is a requirement for all external suppliers to Ford Motor Company.

The principle of quality at Ford Motor Company is far more than a mere checklist undertaken as part of the manufacturing process; it is a deeply rooted internal culture and a way of life, creating ongoing consciousness of commitment in the life of every employee.

Ford Struandale Engine Plant has achieved the highest rating during the Powertrain QOS audit by Lee Scott in June 2009 (Ford Europe PTO Quality Office). According to Lee, the plant has demonstrated great improvements and has consequently achieved a level 8 (top level) during the assessment (FPS newsletter, June 2009).

The next chapter will outline the research methodology adopted in this study.

CHAPTER FOUR
RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

In chapter three the reader was introduced to the programmes and systems used at Ford Struandale Engine Plant.

This chapter describes the broad methodology followed in the empirical part of the study. It consists of research design, research paradigm, sampling, data collection, reliability and validity and response rate.

The main problem mentioned in chapter one was: **What are the underlying factors that are hindering the improvement of overall equipment effectiveness at Ford Struandale Engine Plant?**

The primary objective of this study is to identify how to improve Overall Equipment Effectiveness (OEE) at Ford Struandale Engine Plant by investigating factors that influence OEE.

In order to address the above mentioned challenge, the following secondary objectives need to be investigated:

i) What the literature reveals in terms of how to calculate OEE
ii) What the contributing factors are that influence OEE
   - Availability
   - Performance efficiency
   - Quality rate
iii) What the impact is of the Six Big Losses on OEE
   - Breakdown losses
   - Setup and adjustment losses
   - Idling and minor stoppage losses
   - Reduced speed losses
   - Startup rejects

- Production rejects

iv) What is the Ford Struandale Engine Plant performance is on each of these aspects
   - Availability
   - Performance efficiency
   - Quality rate

v) What impact does training have on OEE at Ford Struandale Engine Plant?
   - What do people at Ford Struandale Engine Plant feel?
   - What has Ford Struandale Engine Plant done?

vi) Ford Struandale Engine Plant has programmes to improve OEE. These programmes include:
   - Ford Total Productive Maintenance
   - Human factors
   - Quality factors

   What their effectiveness is

The first, second and third secondary objectives were discussed in chapter one, describing Overall Equipment Effectiveness, the three elements of OEE and the Six Big Losses.

The fourth and sixth secondary objectives were discussed in chapter three, describing Ford Total Productive Maintenance, ergonomics and human factors and quality factors at Ford Struandale Engine Plant. The fourth secondary objective is also described in the form of data and graphs presented in annexture C, D and E.

The second to the fifth secondary objectives will be discussed in chapter five when interpreting and discussing the findings from the questionnaires.

In order to verify that the findings in the literature and the Ford procedures are implemented at FSEP an empirical study was conducted. The empirical study will help resolve the secondary objectives. The manner in which the secondary objectives will be addressed is explained in this chapter.

4.2 THE THEORY OF RESEARCH DESIGN

There is considerable difference between "knowing" something is true and "proving" it is true. We may "know" that we are "right" but have great difficulty in "proving" it. Proof is public and requires agreement on rules of explanation and evidence. A research design is a set of logical procedures that if followed enables one to obtain the evidence to determine the degree to which one is right or wrong (Labovitz & Hagedorn, 1981:42).

Research design is the "science (and art) of planning procedures for conducting studies so as to get the most valid findings" (Vogt, 1993:196). Research design provides a detailed plan which is used as a guide and focuses the research (Collis & Hussey, 2003:113).

4.2.1 Research Paradigm

According to Collis and Hussey (2003:47), there are two main research paradigms and they are positivist (quantitative) and phenomenological (qualitative) paradigms.

(a). Qualitative research

A phenomenological study is a study that attempts to understand people's perceptions, perspectives, and understanding of a particular situation (Leedy & Ormrod, 2001:153). Qualitative research believes that the researcher's ability to interpret and make sense of what s/he sees is critical for an understanding of any social phenomenon (Leedy & Ormrod, 2001:147). The researchers also believe that there is not necessarily a single, ultimate truth to be discovered. Instead, there may be multiple perspectives held by different individuals, with each of these perspectives having equal validity or truth (Creswell, 1998; Guba & Lincoln, 1988).

Qualitative research is typically used to answer questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participants' point of view (Leedy & Ormrod, 2001:101).

(b). Quantitative research

Quantitative research is used to answer questions about relationships among measured variables with the purpose of explaining, predicting and controlling

phenomena. This approach is sometimes called the traditional, experimental or positivist approach (Leedy & Ormrod, 2001:101).

The quantitative research is used to answer questions about relationships among measured variables and it usually ends with confirmation or disconfirmation of the hypotheses that will be tested.

(c). Qualitative versus Quantitative

A summary of the main differences between qualitative and quantitative research are presented in Table 4.1. This table shows how quantitative and qualitative research differs in terms of objective/purpose, sample, data collection, data analysis and outcome.

Quantitative researchers seek explanations and predictions that will generalise to other persons and places. The intent is to establish, confirm or validate relationships and to develop generalisations that contribute to theory. Qualitative researchers seek a better understanding of complex situations. Their work is often exploratory in nature and they may use their observations to build theory from the ground up (Leedy & Ormrod, 2001:102).

Both approaches involve similar processes (for example, formation of one or more hypotheses, review of the related literature, collection and analysis of data). Yet these processes are often combined and carried out in different ways, leading to distinctly different research methods. For instance, quantitative research usually starts with a specific hypothesis to be tested. The variables to be studied are isolated, controlled for extraneous variables and a standardised procedure is used to collect the data. In contrast, qualitative researchers often start with general research questions rather than specific hypotheses, collect an extensive amount of verbal data from a small number of participants, organise these data into some form that gives them coherence and use verbal descriptions to portray the situation they have studied (Leedy & Ormrod, 2001:101).

A quantitative study usually ends with conformation or disconfirmation of the hypotheses that were tested. Qualitative study is more likely to end with tentative answers or hypotheses about what was observed. These tentative hypotheses may form the basis of future studies (perhaps quantitative in nature) designed to test the proposed hypotheses. In this way, qualitative and quantitative approaches represent complementary components of the research process. To some extent, quantitative and qualitative research designs are appropriate for answering different kinds of questions. As a result more is learned about the world when there are both quantitative and qualitative methodologies at one's disposal than when researchers are limited to only one approach or the other (Leedy & Ormrod, 2001:101).

Table 4.1: Qualitative vs Quantitative Research

	Qualitative Research	**Quantitative* Research**
Objective / purpose:	To gain an understanding of underlying reasons and motivations. To provide insights into the setting of a problem, generating ideas and/or hypotheses for later quantitative research to uncover prevalent trends in thought and opinion	To quantify data and generalise results from a sample to the population of interest. To measure the incidence of various views and opinions in a chosen sample. Sometimes followed by qualitative research which is used to explore some findings further
Sample	Usually a small number of non-representative cases. Respondents selected to fulfill a given quota	Usually a large number of cases representing the population of interest. Randomly selected respondents
Data collection	Unstructured or semi-structured techniques e.g. individual depth interviews or group discussions	Structured techniques such as on-street or telephone interviews
Data analysis	Non-statistical	Statistical; data is usually in the form of tabulations. Findings are conclusive and usually descriptive in nature.
Outcome	Exploratory and/or investigative. Findings are not conclusive and cannot be used to make generalizations about the population of interest. Develop an initial understanding and sound base for further decision-making	Used to recommend a final course of action

Source: http://www.snapsurveys.com/techadvqualquant.shtm

The purpose of this study is to identify what should be done at FSEP in order to improve Overall Equipment Effectiveness (OEE) of the organisation under consideration by investigating factors that influence OEE.

Combined elements of both approaches have been adopted in this study. According to Leedy and Ormrod (2001:103), by making the distinction between quantitative and qualitative research, it is not meant to imply that these approaches are mutually exclusive – that a researcher must choose to use one or the other of them for any particular study. In fact, researchers often combine elements of both approaches.

4.3 THE METHOD OF RESEARCH APPLIED FOR THIS STUDY

The method applied in this study was conducted in a manner that ensures that the study will satisfactorily answer the primary and secondary objectives. The method followed was the academic literature study which laid foundation of the research. Books, the Internet and journals were used. The other literature was derived from Ford's work instructions, company policies, productions systems, company intranet and management reports.

4.3.1 Literature Study

A literature study was conducted in chapter two. It revealed how to calculate OEE, what the contributing factors are that influence OEE, what the impact is of the Six Big Losses on OEE and what the role of TPM in OEE improvement is.

4.3.2 Ford Literature Study

In chapter three a further literature study was conducted on the current policies, strategies, management report and work instructions at Ford Struandale Engine Plant, Port Elizabeth in the Eastern Cape in order to understand the current situation at Ford and also to see the alignment of academic literature and real situation literature.

- Ford Struandale Engine Plant has processes to improve OEE. These processes include:
    - Ford Total Productive Maintenance
    - Human factors
    - Quality factors

- What the Ford Struandale Engine Plant performance is on each of these aspects:
  - Availability
  - Performance efficiency
  - Quality rate

4.3.3 Empirical Study

The empirical study was conducted using questionnaires that were distributed to the team leaders and artisans at Ford Struandale Engine Plant. These questionnaires were hand delivered to 23 team leaders and 23 artisans.

The Six Big Losses were integrated into sections C, D and E of questionnaires as they have a bearing on these sections. Section G also generalised all the training that could possibly be relevant to the research study.

The questionnaires were physically distributed to team leaders and artisans at Ford Struandale Engine Plant. The questionnaires will be used to determine:

- What impact training has on OEE:
  - What people at Ford Struandale Engine Plant feel
  - What Ford Struandale Engine Plant has done
- Ford Struandale Engine Plant has processes to improve OEE. These processes include:
  - Ford Total Productive Maintenance
  - Human factors
  - Quality factors

4.3.3.1 The Sampling Design

A sample is made up of some of the members of the population. A population may refer to a body of people or to any other collection of items under consideration for research purposes (Collis & Hussey, 2003:155). The sample should be carefully chosen so that, through it, the researcher is able to see all the characteristics of the

total population in the same relationship that they would be seen were the researcher, in fact, to impact the total population (Leedy & Ormrod, 2001:211).

Successful statistical practice is based on focused problem definition. In sampling, this includes defining the population from which the sample is drawn. A population can be defined as including all people or items with the characteristic one wish to understand. Because there is very rarely enough time or money to gather information from everyone or everything in a population, the goal becomes finding a representative sample (or subset) of that population (http://en.wikipedia.org/wiki/ Sampling).

In this study there are two types of sampling that will be used: snowball and stratified sampling. Snowball sampling will be used to construct the questionnaires targeting the task team (one millwright, one fitter and one team leader). The snowball sampling or networking is associated with phenomenological studies where it is essential to include people with experience of phenomena being studied in the sample (Collis & Hussey, 2003:159). Stratified sampling will be used as the sampling frame consists of the following strata: electricians, fitters and team leaders. The total population consists of 46 participants: Eight electricians, 15 fitters and 23 team leaders. Confidentiality will be guaranteed to all the respondents. The researcher will also work closely with Human Resources to ensure that all the unethical issues are dealt with before the study commences.

The sampling processes and procedures allow the researcher to make better and informed decisions on the basis on information received from the sample.

4.3.3.2 Data Collection Methods

There will always be a combination of quantitative or qualitative inputs into one's data generating activities. The balance depends on one's analytical requirements and the overall purpose of the research. Quantitative and qualitative approaches to data collection present a collection of both advantages and disadvantages. A main advantage of a quantitative approach to data collection is the relative ease and speed with which the research can be conducted (Collis and Hussey, 2003:162).

Table 4.2: Advantages and disadvantages of various data collection techniques

Technique	Advantages	Possible constraints
Using available information	Is inexpensive, because data is already there. Permits examination of trends over the past.	Data is not always easily accessible. Ethical issues concerning confidentiality may arise. Information may be imprecise or incomplete.
Observing	Gives more detailed and context-related information. Permits collection of information on facts not mentioned in an interview. Permits tests of reliability of responses to questionnaires.	Ethical issues concerning confidentiality or privacy may arise. Observer bias may occur. (Observer may only notice what interests him or her.) The presence of the data collector can influence the situation observed. Thorough training of research assistants is required.
Interviewing	Is suitable for use with both literates and illiterates. Permits clarification of questions. Has higher response rate than written questionnaires.	The presence of the interviewer can influence responses. Reports of events may be less complete than information gained through observations.
Small scale flexible interview	Permits collection of in-depth information and exploration of spontaneous remarks by respondents.	The interviewer may inadvertently influence the respondents. Analysis of open-ended data is more difficult and time-consuming.
Larger scale fixed interview	Is easy to analyse.	Important information may be missed because spontaneous remarks by respondents are usually not recorded or explored.
Administering written questionnaires	Is less expensive. Permits anonymity and may result in more honest responses. Does not require research assistants. Eliminates bias due to phrasing questions differently with different respondents.	Cannot be used with illiterate respondents. There is often a low rate of response. Questions may be misunderstood.
Participatory and projective methods	Provide rich data and may have positive spin offs for knowledge and skills by researchers and informants.	Require some extra training of researchers.

Source: http://www.idrc.ca/en/ev-56606-201-1-DO_TOPIC.html

The data collection method that was used in the study was the questionnaire and focus groups. Table 4.2 (above) summarises the advantages and disadvantages of various data collection techniques.

(a) The questionnaire

Questionnaires are associated with both positivistic and phenomenological methodologies. A questionnaire is a list of carefully structured questions, chosen after considerable testing, with a view to eliciting reliable responses from a chosen sample. The aim is to find out what selected group of participants do, think or feel (Collis & Hussey, 2003:173).

The questionnaire used in this research has been formatted according to the five-point Likert Scale that ranges from (1) Strongly Disagree to (5) Strongly Agree. A rating/Likert Scale is more useful when a behaviour, attitude or other phenomenon of interest needs to be evaluated on a continuum of, say, "inadequate" to "excellent," "never" to "always," or "strongly disagree" to "strongly agree" (Leedy & Ormrod, 2001:197). The advantages of the Likert Scale are flexibility, economy, ease of composition and the fact that it is possible to obtain summaries of data from clusters of items.

The questionnaire was designed to answer secondary objectives that could not be satisfactorily answered by the literature study discussed in the previous chapters. The questionnaire is divided in to nine sections: section A is about the biographical information of the respondent, section B is OEE, section C is availability, section D is performance efficiency, section E is quality, section F is TPM, section G is training and understanding, section H is human factors and section I is open-ended questions for respondents to give suggestions on how the company can improve sections C to G.

Annexure A indicates the types of questions that are included in the chosen data collection method.

(b) Design of Questionnaire

Question design is concerned with the type of questions, their wording, the reliability and validity of the responses (Collis & Hussey, 2003:174). Leedy and Ormrod (2001:202) suggest that the following guidelines be used for developing a

questionnaire that encourages people to be co-operative and yields responses one can use and interpret:

- Keep it short and as brief as possible;
- Use simple, clear, unambiguous language;
- Check for unwarranted assumptions implicit in the questions asked;
- Word the questions in ways that do not give clues about preferred or more desirable responses;
- Check for consistency;
- Determine in advance how the responses will be coded;
- Keep the respondent's task simple;
- Provide clear instructions;
- Give a rationale for any items whose purpose may be unclear;
- Make the questionnaire attractive and professional-looking;
- Conduct a pilot test; and
- Scrutinise the almost-final product carefully to make sure it addresses the researchers' needs.

The purpose of the questionnaire must be apparent; the respondents must know the context in which the questions are being posed. This can be achieved by either attaching a covering letter or by starting off the questionnaire with an explanatory paragraph (Collis & Hussey, 2003:174).

(c) Questionnaire cover letter

In the covering letter and accompanying questionnaire (annexure A), the aim of the research was briefly explained and the respondent was also assured that the content of the questionnaire would be regarded as strictly confidential as indicated in annexure A. The covering letter was sent out attached to the questionnaire to the participants at Ford Struandale Engine Plant.

(d) Task Team

Focus groups are normally associated with a phenomenological methodology. They are used to gather data relating to the feelings and opinions of a group of people who

are involved in a common situation. Under the guidance of a group leader, selected participants are stimulated to discuss their opinions, reactions and feelings about a product, service and type of situation or concept (Collis and Hussey, 2003:166).

A group of people was brought together to discuss what they feel is the cause of low machine uptime and how it can be improved. The group consists of one millwright, one fitter, one team leader and is lead by the FTPM coordinator. In this document the focus group is refer to as a task team.

4.3.3.3 Data Analysis

Data analysis is a process of gathering, modeling and transforming data with the goal of highlighting useful information, suggesting conclusions and supporting decision-making. Data analysis has multiple facets and approaches, encompassing diverse techniques under a variety of names, in different business, science and social science domains.

Data analysis is more than number crunching. It is an activity that permeates all stages of a study. Concern with analysis should (1) begin during the design of a study, (2) continue as detailed plans are made to collect data in different forms, (3) become the focus of attention after data are collected, and (4) be completed only during the report writing and reviewing stages.

The basic thesis of this paper is that successful data analysis, whether quantitative or qualitative, requires (1) understanding a variety of data analysis methods, (2) planning data analysis early in a project and making revisions in the plan as the work develops; (3) understanding which methods will best answer the study questions posed, given the data that have been collected; and (4) once the analysis is finished, recognising how weaknesses in the data or the analysis affect the conclusions that can properly be drawn. The study questions govern the overall analysis, of course. But the form and quality of the data determine what analyses can be performed and what can be inferred from them. This implies that the evaluator should think about data analysis at four junctures:

- when the study is in the design phase,

- when detailed plans are being made for data collection,
- after the data are collected, and
- as the report is being written and reviewed

The data collected by the questionnaires will be analysed using histograms, pie charts and tables generated from Excel Spreadsheet.

4.3.3.4 Validity and Reliability

Validity is the extent to which the research findings accurately represent what is really happening in the situation. An effect or test is valid if it demonstrates or measures what the researcher thinks or claims it does (Collis & Hussey, 2003:58). Leedy and Ormrod (2001:98) argue that validity of a measurement instrument is the extent to which the instrument measures what it is supposed to measure. It takes different forms, each of which is important in different situations:

- Face validity is the extent to which, on the surface, an instrument looks like it is measuring a particular characteristic;
- Content validity is the extent to which a measurement instrument is a representative sample of the content area being measured;
- Criterion validity is the extent to which the results of an assessment instrument correlate with another, presumably related measure; and
- Constructive validity is the extent to which an instrument measures a characteristic that cannot be directly observed but must instead be inferred from patterns in people's behaviour.

Leedy and Ormrod (2001:99) state that the reliability of a measurement instrument is the extent to which it yields consistent results when the characteristic being measured has not changed. The following are forms of reliability that are frequently of interest in research studies:

- Interrater reliability is the extent to which two or more individuals evaluating the same product or performance give identical judgments;
- Internal consistency reliability is the extent to which all the items within a single instrument yield similar results;

- Equivalent forms reliability is the extent to which two different versions of the same instrument (e.g. "Form A" and "Form B" of a scholastic aptitude test) yield similar results; and
- Test-retest reliability is the extent to which the same instrument yields the same result on two different occasions.

Reliability is concerned with the findings of the research and is one aspect of the credibility of the findings. If a research finding can be repeated, it is reliable. Repeating a research study to test the reliability of the results is known as replication and is very important in positivistic studies where reliability is usually high.

Under a phenomenological paradigm the criterion of reliability may not be given so much status, or it may be interpreted in a different way. It is not important whether qualitative measures are reliable in the positivistic sense, but whether similar observations and interpretations can be made on different occasions and/or by different observers.

4.6 SUMMARY

In this chapter the research methodology being followed for this research was described in depth. This chapter laid the framework of the study and documented all the steps followed in this study.

The data collected by means of questionnaires will be analysed and discussed in greater detail in chapter five.

CHAPTER FIVE
RESULTS: PRESENTATION AND DISCUSSION

5.1 INTRODUCTION

In chapter four the research methodology was discussed. In this chapter an analysis and interpretation of data obtained from the empirical study will be discussed. The objective of this chapter is to analyse and investigate the opinions of the respondents.

The objective of the survey is to determine how the respondents felt about Ford Struandale Engine Plant's performance with respect to availability, performance efficiency and quality. The researcher will also attempt to highlight how effective the programmes are: Ford Total Productive Maintenance, human factors and quality factors as the FSEP literature indicated that these programmes are in place but the question was how effective are they.

The questionnaires were distributed amongst the team leaders and artisans of Ford Struandale Engine Plant and the population size comprised 46 individuals. The researcher will now review and analyse the responses received.

5.2 ANALYSIS OF THE EMPIRICAL RESULTS

The respondents that participated in the research were employees from Ford Struandale Engine Plant located in Port Elizabeth, South Africa.

The analysis will cover three key areas: the response rate, the questionnaire which consists of nine sections and the response from the focus group.

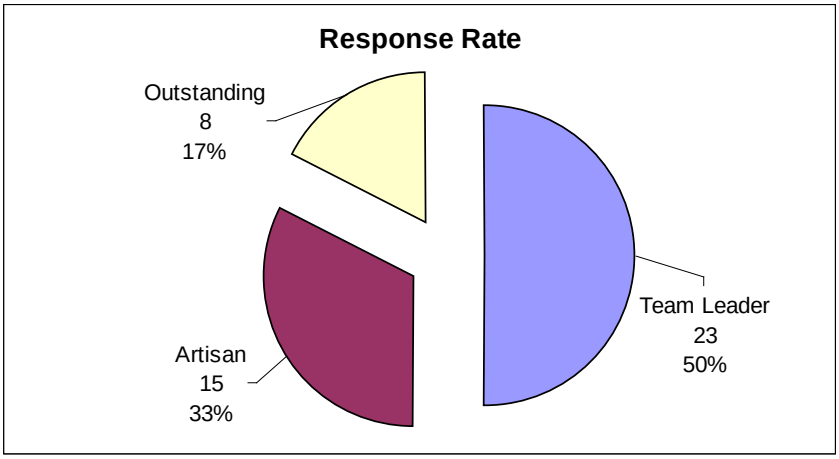
5.2.1 Response Rate

From a population sample of 46 respondents, 38 responses were received, making a response rate of 83 percent. The responses that were not received constituted only 17 percent of the sample. The overall response rate is depicted in Table 5.1:

Table 5.1: Overall response rate.

Response	Number of responses	Number of responses by position	
		Team Leader	Artisan
Issued	46	23	23
Received	38	23	15
Outstanding	8	0	8
Percentage	**83%**	**100%**	**65%**

Chart 5.1: Overall response rate converted to a pie chart.



A total of 46 questionnaires were handed to employees targeting 23 team leaders and 23 artisans. The response rates from team leaders and artisans were 100 percent and 65 percent respectively. The reason for the poor response from artisans was due to the fact that they are always busy fire fighting the breakdowns and there was not enough time to sit them down to discuss the questionnaires and allow them time to complete them as was the case with team leaders.

5.2.2 Questionnaires

The questionnaires that were distributed to the employees consist of nine sections from section A to section I. Section A is the biographical information. From section B to H the questions are designed on the Likert Scale model and cover OEE, availability, performance efficiency, quality rate, TPM, training and understanding and human factors. Section I has the open-ended questions whereby the respondents were asked their own opinion on how Ford Struandale Engine Plant can improve section C to G. In order to analyse the Likert-Scaled response a decision was taken to

group all the “strongly agree” and “agree” responses together. The same was done with the “strongly disagree” and “disagree” data.

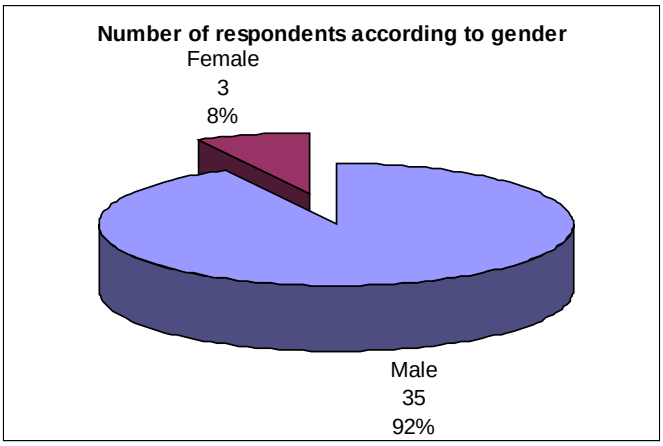
(a) Section A: Biographical information

The biographical information was analysed according to gender, age, current position, qualification and years of service at Ford Struandale Engine Plant. Table 5.2 below gives a summary of the biographical information. This will be presented in detail in chart 5.2 to chart 5.6.

Table 5.2: Section A - Overall biographical response.

What is your gender?		
Gender	**Number of responses**	**Percentage of responses**
Male	35	92%
Female	3	8%
Total	**38**	**100%**
What is your age?		
Age	**Number of responses**	**Percentage of responses**
18 – 25 years	0	0%
26 – 35years	10	26%
36 + years	28	74%
Total	**38**	**100%**
What is your current position?		
Position	**Number of responses**	**Percentage of responses**
Team leader	23	61%
Artisan	15	39%
Total	**38**	**100%**
What is your highest qualification?		
Qualification	**Number of responses**	**Percentage of responses**
High school	10	26%
Diploma	28	74%
Degree	0	0%
Total	**38**	**100%**
Years of service at Ford		
Years of service	**Number of responses**	**Percentage of responses**
0 – 1 years	0	0%
2 – 5 years	1	3%
6 – 10 years	17	45%
11 – 15 years	20	53%
16 + years	0	0%
Total	**38**	**100%**

Chart 5.2: Number of respondents according to gender.



The majority of the respondents were male respondents. This is actually a true reflection of the gender ratio on these positions in the plant. The survey indicated 92 percent of respondents were male and only eight percent were female as indicated in Chart 5.2 above.

Chart 5.3: Number of respondents by age

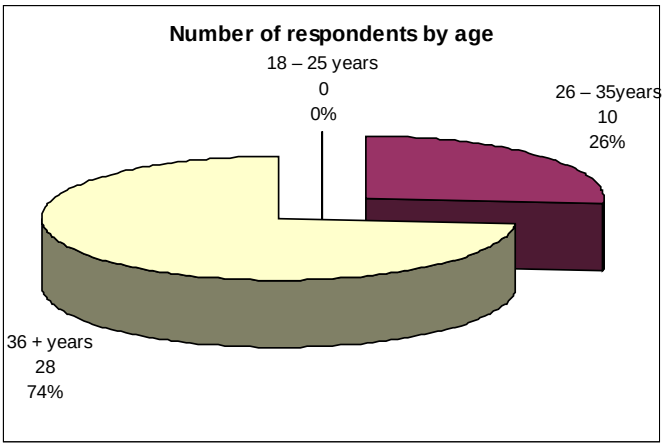
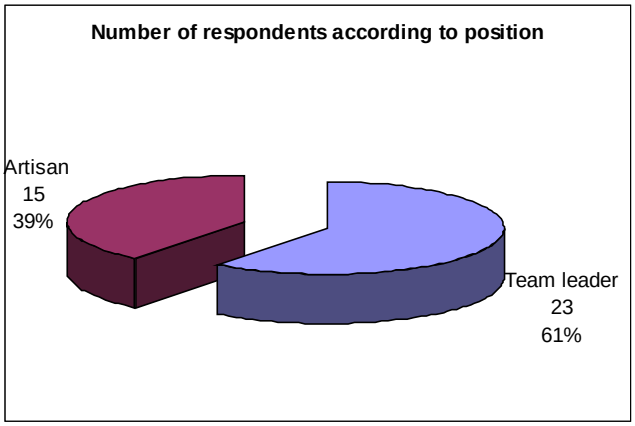


Chart 5.3 illustrates that 74 percent of the respondents are 36+ years and 26 percent are between the ages of 26 – 35 years. This actually indicates the level of maturity of the respondents as there are no respondents between the ages of 18 – 25 years. The respondents are at an age where responsibility is assumed. The benefit for the company is that mature responsible employees usually have a well-developed sense of what is right or wrong.

Chart 5.4: Number of respondents according to position



The majority of respondents, as indicated in chart 5.4 above, were team leaders with a 100 percent response rate, forming 61 percent of the respondents. The artisan response rate was 65 percent and counted 39 percent of the respondents. This was due to the fact that the team leaders normally have a session for training where they can be found together and be addressed. On the other hand, artisans are busy doing planned maintenance or fire fighting breakdowns at that time and this lead to a poor response rate.

Chart 5.5: Number of respondents by qualification

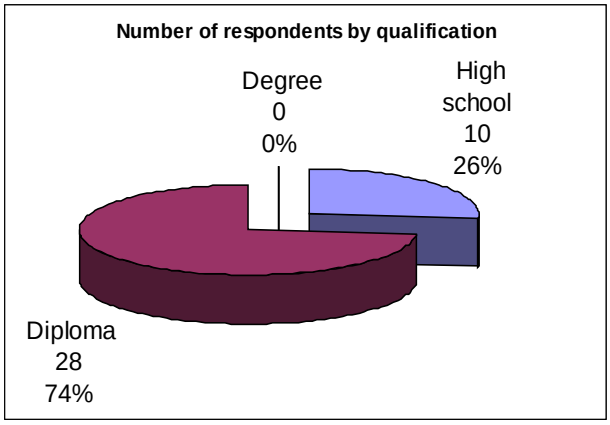


Chart 5.5 indicates that the majority of the respondents have obtained a diploma and a few have only completed high school level. This translates to 74 percent and 26 percent respectively and there were no respondents with any degrees. This is not surprising because most of the team leaders have been encouraged to complete their diplomas and the company offered them bursaries. Some have already obtained diplomas. When looking at chart 5.4 it can be seen that the majority of the respondents were team leaders.

Chart 5.6: Number of respondents according to years of service.

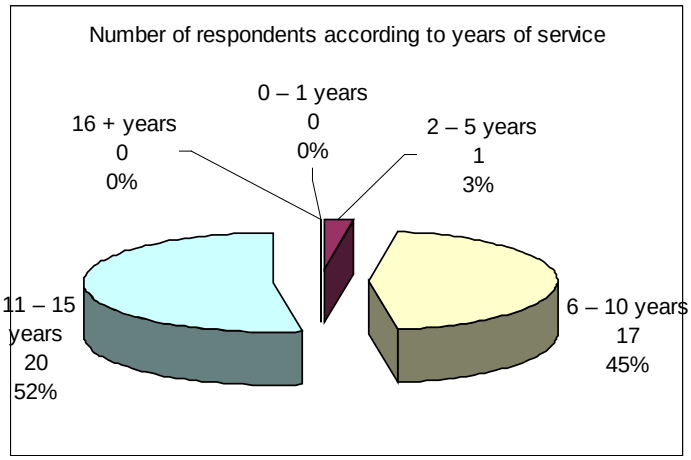


Chart 5.6 shows that most of the respondents have been in the company long enough to understand the programmes and systems being used in the company. It can be seen that 97 percent of the respondents have served the company for six years or longer. Only 3 percent have fewer than six years of service. This affirms that the sampled respondent are familiar with and have been involved with the company programmes and processes long enough to make informed judgments.

(b) Section B: Overall Equipment Effectiveness (OEE)

Section B tests the understanding and the level of engagement of the respondent on Overall Equipment Effectiveness. The questions were structured in a manner that will highlight the elements such as operator involvement in collecting data, the understanding and elimination of the Six Big Losses and management/union involvement.

Table 5.3 below depicts a summary of the respondents' opinions on how they feel about the OEE in their working area.

Table 5.3: Section B - Overall Equipment Effectiveness response

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	I do understand the overall equipment effectiveness of the machines in my work area.	95%	5%	0%
2	Operators collect data for their machines.	61%	5%	34%

3	I do understand the Seven Big Losses (breakdowns, minor stops, tooling losses, startup losses, etc).	89%	3%	8%
4	The company does identify and eliminate the various losses, then good production increases.	37%	21%	42%
5	OEE is used to prioritise the improvement opportunities and forming cross-functional teams to eliminate root cause of the loss.	53%	24%	24%
6	The company does have a changeover process.	61%	21%	18%
7	Plant leadership (union and management) are on the plant floor daily to provide assistance and improve OEE.	37%	8%	55%

All the “agree” or “strongly agree” responses were combined. The same was done with “disagree” and “strongly disagree” in order to make the analysis more meaningful. This table is converted to a form of graphic representation and discussed more in depth in chart 5.7 below.

Chart 5.7: Graphic representation of Overall Equipment Effectiveness response.

According to the chart 5.7 above, 95 percent of the respondents agree or strongly agree that they understand the OEE of their machines and 89 percent understand the Seven Big Losses. Operators collect data for their machines as 61 percent of respondents indicated.

It seems to be a concern that although data is collected and people do understand the big losses, there is not much attempt at eliminating these losses. About 42 percent of the respondents feel that the company is not doing much to eliminate these losses. Therefore they could not see good production based on elimination of the losses.

The respondents feel that the company does have changeover processes although the company is presently not doing too many changeovers. Of the respondents, 61 percent feel that the processes are in place.

The respondents also strongly disagree or disagree that the leadership is involved in providing shop-floor assistance to improve OEE. Most of the questionnaires actually indicated that management does give assistance but not so the union.

(c) Section C: Availability

The availability section was designed to understand the availability and visibility of the information for the end-users to have a good understanding of their machine uptime. It was determined that it is not doing any justice having the data on computers and not sharing it with the operators involved. In the section there is a connection between breakdowns, idling and minor stops losses with availability as the literature revealed that the two big losses that have a direct influence on availability are actually breakdowns and setup and adjustments. The task team also revealed that the major concern on the production lines is quick fixes, which contributes to a large extent to breakdowns.

The table 5.4 below depicts a summary of the respondents by question on how they feel about availability on their work areas.

Table 5.4: Section C - Availability response.

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	The machine availability of my area is visible and understood by everyone.	55%	21%	24%
2	Machinery stops often for maintenance problems.	71%	3%	26%
3	Every breakdown is captured and trended.	47%	26%	26%

4	All tooling losses are captured and trended.	61%	32%	8%
5	Does the machine often stop for idling and minor stops?	71%	5%	24%
6	All the setup and adjustments are recorded and trended.	39%	24%	37%
7	The company does have a changeover procedure.	63%	16%	21%
8	There are processes in place to reduce the changeover time.	42%	37%	21%
9	There are processes in place to analyse breakdowns and the root causes are identified and permanently fixed.	39%	5%	55%

All the responses “agree” or “strongly agree” were combined. The same was done to “disagree” and “strongly disagree” in order to make the analysis more meaningful. This table is converted to a form of graphic representation and discussed in more depth in chart 5.8 below:

Chart 5.8: Graphic representation of availability response.

According to respondents, 55 percent feel that the machine availability is visible and understood by everyone. This is a concern that only just more than 50 percent of people understand or have a chance to know the uptime of their equipment. The company needs to make sure that most of this information is available to the shop

floor so that they can start initiating their own little projects to try and improve the uptime of their equipment.

The respondents also feel strongly (71 percent) that most stoppages are due to maintenance-related problems. This is also not a surprising concern as it was indicated previously that the task team highlighted the point that the production lines are doing more quick fixes and less planned maintenance work as the example of the blockline machining line shows in figure 3.2.

The survey indicates that the 63 percent of the people feel that the company does have changeover procedure but only 42 percent feel that there are processes to reduce the changeovers. This indicates that the company is not following the Single Minute Exchange of Dies (SMED) programme because the SMED encourages the company to keep on improving the changeover times.

It is also clear that there are no processes followed to analyse the problem, to get to the root cause and to permanently fix the problem. If the processes are in place they are simply not being followed religiously or used to improve the business. According to the survey, 55 percent feel that the processes are not being followed. Therefore the root causes are not identified and the problems are not properly resolved.

(d) Section D: Performance Efficiency

- This section was designed to indicate that the employees involved in production actually do understand their performance on the lines. There was also a link with the two big losses and the performance efficiency as the theory indicated that idling and minor stops and cycle time are the major factors affecting availability.

The table 5.5 below depicts a summary of the respondents by question on how they feel about performance efficiency on their work areas:

Table 5.5: Section D – Performance efficiency response.

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	The performance efficiency of my area is visible and understood by everyone.	66%	18%	16%
2	Does the machine often stop for idling and minor stops?	68%	0%	32%
3	Does the machine often stop for dirty sensors?	68%	8%	24%
4	Certain machinery has longer cycle time than the design cycle time.	76%	16%	8%
5	When calculating efficiency the time allocated does not add up to 100% (there are always unidentified losses).	84%	16%	0%
6	There are regular cycle time studies being conducted on the machinery to ensure they still operate at their designed cycle time.	34%	26%	39%

All the “agree” or “strongly agree” responses were combined. The same was done with “disagree” and “strongly disagree” in order to make the analysis more meaningful. This table is converted to a form of graphic representation and discussed in more depth in chart 5.9 below:

Chart 5.9: Graphic representation of performance efficiency response.

The survey indicates that 66 percent of the respondents understand the performance efficiency of their lines and the figures are visible and understood by everyone. This figure is more surprising because the natural workgroup (NWG) teams sit every Wednesday and review and discuss their performance, using the SQDCME metrics. Therefore there should be a common understanding across the work group members because both team leaders and artisans with operators are part of the NWG meetings.

The majority of respondents (68 percent of them) also feel that the machine stops more for idling and minor stops. It is usually common that if the machines are not properly maintained they usually stop for minor issues like misalignment of sensors and metal chips on the reflectors. That will only require an operator to wipe the reflectors and carry on running the machine. It was also confirmed by the survey that 68 percent believe that the machine often stop for dirty sensors which is the same percentage that believe that machinery often stops for idling and minor stoppages.

The respondents also strongly believe (84 percent) that when calculating the performance efficiency, the time allocated does not add up to 100 percent. Normally the main reason for this is exactly what the respondents indicated: that most of the time the machines stop for minor stops and an operator will only wipe the reflectors and continue running. Most of the time these stoppages are not properly collected and captured as a history of the machine so that the maintenance team can identify and resolve them: they merely become of the process for the operators.

The respondents (76 percent of them) believe that some of the machines have longer cycle times than the design cycle time. At the same time only 34 percent of the respondents believe that there are no regular cycle time studies being conducted to ensure the machines are still operating at their designed cycle times. One of the reasons that could cause people to believe that machines operate at longer cycle times is because of the minor stoppages that are not properly recorded - they only look at the output and compare it to downtime. When there is no downtime, the output is low and they have the assurance that the machine was manned all the time. Then they believe that it has a longer cycle time.

(e) Section E: Quality rate

This section of quality was integrated with the two big losses, startup rejects and production rejects, as the theory indicated that these losses have a major influence on quality. This was done to understand the performance of the company and how people feel about the quality of their product.

The table 5.6 below depicts a summary of the respondents by question on how they feel about the quality of their work areas:

Table 5.6: Section E – Quality rate response.

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	The quality rate of my area is visible and understood by everyone.	76%	18%	5%
2	The company does record the machine scrap, rejects and assembly return.	95%	3%	3%
3	The company does record the startup rejects.	71%	18%	11%
4	The company utilises Poka yoke to prevent errors.	87%	11%	3%
5	The company has measures in place to protect the customer.	82%	18%	0%
6	The company strives to continuously improve its products and processes.	76%	13%	11%

This table is converted to a form of graphic representation and discussed more in depth in chart 5.10 below.

All the “agree” or “strongly agree” responses were combined. The same was done with “disagree” and “strongly disagree” in order to make the analysis more meaningful.

The average response of 81 percent answered all the questions related to quality very positively. The majority of the respondents strongly believe that almost everything that was supposed to be in place for quality is actually in place.

Chart 5.10: Graphical representation of quality rate response.

(f) Section F: Total Productive Maintenance

This section of Total Productive Maintenance was designed to understand from the respondents that the key elements of TPM are in place and they are used to improve the business performance. TPM is one of the lean manufacturing tools used to ensure equipment reliability. Lean manufacturing believes in Just In Time therefore if the company is using the JIT system, then it is a key measure in ensuring that machine uptime is always high. TPM is the right programme to ensure that because the company cannot afford to have unreliable machines as there are always minimum stock levels of finished goods.

The table 5.7 below depicts a summary of the respondents by question on how they feel about Total Productive Maintenance on their work areas.

Table 5.7: Section F – Total Productive Maintenance response.

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	Maintenance artisans provide support to operators by having direct contact with the operator.	89%	3%	8%
2	Maintenance artisan's do preventive maintenance checks.	66%	16%	18%

3	Chronic problems with equipment are identified and eliminated.	34%	24%	42%
4	Condition monitoring has improved the reliability of the machinery in production areas.	39%	42%	18%
5	Maintenance Operating System has been communicated to plant employees.	37%	18%	45%
6	Detailed roles and responsibilities, and levels of authority for all maintenance personnel are well-defined, communicated, updated and understood plant-wide.	42%	13%	45%
7	Equipment is made available for maintenance, when scheduled, plant-wide.	37%	16%	47%
8	Appropriate Data Collection and Analysis (e.g. OEE, uptime) is used by the facility to eliminate equipment related losses	42%	29%	29%
9	Operators conduct daily checks on machinery and equipment they operate.	74%	13%	13%
10	People are encouraged to make and implement suggestions.	63%	8%	29%

All the “agree” or “strongly agree” responses were combined. The same was done with “disagree” and “strongly disagree” in order to make the analysis more meaningful. This table is converted to a form of graphic representation and discussed in more depth in chart 5.11 below:

Chart 5.11: Graphical representation of Total Productive Maintenance response.

The respondents believe that artisans provide support to operators and they use the operators as the first line of defense when there is a problem on the machine because operators see the symptoms before the machine actually stops. At least 90 percent of the time this leads the artisan to the problem and shortens the fault-finding time. There are 89 percent of the respondent who believe that there is a good relationship between artisan and operator.

They also believe (66 percent) that artisans do preventive maintenance checks. The challenge is that when these checks are done there are no spares available to fix the problems identified. According to the feedback from the task team, which will be discussed in detail later, there is concern about the lack of spares. Therefore some of the checks are just ticked on the box and no corrective actions taken. This could be the reason why only 34 percent believe that chronic losses are actually identified and eliminated.

Appropriate data collection and analysis is used by the facility to eliminate equipment related losses. Only 42 percent of the respondents believe that data is collected and analysed to eliminate losses. Generally this sums up the fact that processes for root cause analysis are not followed, therefore the root cause of the problems is not known nor eliminated.

About 74 percent of the respondents believe that operators conduct daily checks on their machinery and equipment. Autonomous Maintenance gives the assurance that operators are doing this on a daily basis.

The majority of the respondents also believe that people are encouraged to make and implement suggestions in the plant. About 63 percent of the respondents believe that if they come up with suggestions, those suggestions are actually implemented.

Generally, the majority of the respondents believe that there are still fundamental processes that are not in place or not being utilised to their full potential.

(g) Section G: Training and understanding

Training and understanding is the key of any programme the company is engaging in because it is the only way to ensure that there is common understanding among the employees at all levels. The training section was designed to generalise for all the elements relevant for the study.

Basically, the Basic Equipment Wellness training gives a good overview of the FTPM processes. It is mainly aimed at operator level to give a good overview of what is expected from a production personnel and their level of involvement.

The table 5.8 below depicts a summary of the respondents by question on how they feel about training and understanding that they received to perform their work better:

Table 5.8: Section G – Training and understanding response.

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	People receive the training they need to do their jobs.	55%	5%	39%
2	People are coached and trained by their leaders/Supervisors.	58%	8%	34%
3	Are people encouraged to improve their knowledge and skills at work?	50%	13%	37%
4	Safety, ergonomic and environmental training programs has been provided for work group members and personnel involved in the maintenance process	74%	13%	13%
5	The facility provides the appropriate training to support the maintenance process	45%	16%	39%
6	I have received the Basic Equipment Wellness training One (BEW1) which involves 7 steps of BEW.	47%	18%	34%
7	I have received Ford Production Systems (FPS) over view training	68%	3%	29%
8	I have received Ford Total Productive Maintenance (FTPM) over view training	66%	8%	26%
9	I have received a Value Stream Map (VSM) training	66%	3%	32%
10	I have received training on 5S.	84%	0%	16%

All the “agree” or “strongly agree” responses were combined. The same was done with “disagree” and “strongly disagree” in order to make the analysis more meaningful. This table is converted to a form of graphic representation and discussed more in depth in chart 5.12 below:

Chart 5.12: Graphic representation of training and understanding response.

The respondents (55 percent of them) have received training to do their jobs better and effectively. There are also operator instructions sheets to train operators on the line for every new workstation they operate.

The respondents believed that supervisors coach them when there is a need for coaching. About 58 percent believe that they are being trained or coached by their leaders. The process conformation is used as a coaching session by the managers when engaging with the shop floor employees.

Only 55 percent of the responses agreed that employees are encouraged to improve their knowledge and skills at work and 13 percent indicated that they were not sure.

The respondents believe that the company provides safety, ergonomic and environmental training. A total of 74 percent of the respondents acknowledge the fact that every Ford employee and contractor, before conducting any job, receives

safety, ergonomic and environmental training. The 74 percent is not a true reflection: a true reflection is 100 percent because the company does not compromise when it comes to this training. It takes place during the induction training.

The respondents believe that the company is not doing enough in giving appropriate training to support maintenance processes. Only 45 percent agree that the facility provides appropriate training to support maintenance processes. The reality is that the majority of the time artisans are not involved in training, because training takes place either when there is a big breakdown and their skills are required to solve the breakdown or on non-production days, when they are expected to do planned maintenance on their machines.

About 66 percent on average of the respondents believe that they have received FPS, FTPM and VSM training, while 84 percent believed that they have received 5S training and are involved in implementing the 5S in their area. The company has developed a 5S standard for the plant and given the responsibility of implementing it to the NWG.

Generally, there is a positive response about training and understanding. Respondents agree that they have received the training required to perform their job better, safer, and more efficiently.

(h) Section H: Human Factors

The human factor section was mainly designed for a general understanding that the company actually cares about the wellbeing of their employees, more especially employees involved in equipment maintenance. This is normally the area that causes more injuries and even fatalities for the company and is responsible for a huge drop in morale. None of the employees wants to get injured or see one of their colleagues injured either.

The table 5.9 below depicts a summary of the respondents by question on what they feel Ford has done to take care of all the human factors in design for maintenance:

Table 5.9: Section H – Human Factors response.

Number	STATEMENT	Strongly agree / Agree	Uncertain	Strongly disagree / Disagree
1	Ford management care for or look after their employees well being.	53%	21%	26%
2	The space provided for workers is large enough for them to perform the required task.	63%	11%	26%
3	The machines are designed to provide failure indications to make troubleshooting fast, simple, and easy.	55%	18%	26%
4	At Ford before you put any part of your body in danger inside or near a machine, you must first isolate and lockout the energies.	100%	0%	0%
5	Operators do basic maintenance and inspect their machines as well as operate them.	53%	16%	32%
6	Ford encourages team work	74%	11%	16%
7	Is there an opportunity for people to acquire and enhance skills and experience and develop their full potential?	50%	13%	37%

All the “agree” or “strongly agree” responses were combined. The same was done to “disagree” and “strongly disagree” in order to make the analysis more meaningful. This table is converted to a form of graphic representation and discussed more in depth in chart 5.13 below:

Chart 5.13: Graphic representation of human factors response.

Chart 5.13 shows that 53 percent of respondents agree that Ford management care for or look after their employees' well-being. This is enhanced by the Employee Wellness Programme.

The respondents also believe that the space provided for workers is large enough for them to perform the required tasks. This is due to risk assessments that are done regularly when there is a change to the layout of the area; industrial engineering also involves the people concerned when doing the layouts.

All the respondents, 100 percent, strongly agree that at Ford before employees put any part of their bodies in danger inside or near a machine, they must first isolate and lockout the energies of the machine: Zero tolerance, 100 percent compliance with ECPL.

About 53 percent of the respondents believe that operators do basic maintenance and inspection of their machines. This is encouraged through Autonomous Maintenance and artisan and operator training where an artisan can train an operator on basic maintenance.

About 74 percent of the respondents acknowledge the fact that Ford Motor Company encourages team work. This is also encouraged up to the shop floor through natural work group meetings.

Only 50 percent of the respondents feel that there is an opportunity for people to acquire and enhance skills and experience and develop their full potential.

(i). Section I: Respondents' opinions

This is the section whereby the respondents are asked to suggest how the company can improve or do things better. The sections that were selected are section C to section G.

Table 5.10 to table 5.14 below are summaries of the respondents' opinions on what the cause of the poor performance on section C to G is and how the company can improve these sections.

Table 5.10: Respondents' opinions on how the company can improve availability.

SECTION C: AVAILABILITY

How can the company improve machine availability?
1. By eliminating quick fixes.
2. Quick response by Artisans - use a siren to call Artisans.
3. FRACAS table & FAR should be filled in.
4. Having the right people doing the correct planning.
5. Do more regular preventive maintenance.
6. Encourage ownership of all equipment to operators and artisans.
7. By doing PM's and have Team leaders and operators as support.
8. Machine availability can only improve if spare parts availability is improved
9. By training their artisans whenever new machinery arrives and provide drawings.
10. Proper reporting of breakdowns, good and real planned maintenance.
11. Train Artisans to do Failure Analysis Report (FAR).

The findings on table 5.10 are related to machine availability, the cause of poor machine availability and how the company can improve it. The main factors that stand out are quick fixes, lack of skills for both supervisor planning and artisans and processes that are not followed properly.

The respondents feel that the quick fixes are a major cause of the poor machine uptime because the artisans will then have to keep on doing temporary fixes that will not last and the machine will stop again. The planning is also not done properly because whenever there is a quick fix done there should be a plan to go back and correct the quick fix. This indicates that the supervisors are not planning properly as these problem areas should be covered when doing corrective maintenance.

The skill issue was also due to a high turnover of employees because of fear and voluntary separation that took place this year.

The processes that are not followed are processes that are used to analyse the failure, get to the root cause and, most importantly, eliminate the root cause. For instance, Failure Analysis Report (FAR) is designed for collecting data, analysing it, getting to

the root cause, permanently fixing the cause and tracking the performance for 30 working days.

The respondents suggest that the company should do more preventive and predictive maintenance. The production team should be made part of the maintenance planning so that they can highlight the concerns that are randomly causing breakdowns. The artisans and production employees also need training on the problem-solving tools and on new machinery.

Table 5.11 below is about summary of performance efficiency, the reasons why the lines are not performing well and the suggested solutions from the respondents. The respondents believe that the main reasons for the lines not performing well are poor planning for tool changes, lack of data capturing and analysis, lack of discipline and quick fixes.

They also suggest that the company should start making people accountable for their jobs. They should start collecting data and have a history of their equipment.

Table 5.11: Respondents' opinions on how the company can improve performance efficiency.

SECTION D: PERFORMANCE EFFICIENCY

How can the company improve performance efficiency?
1. Make sure all tool changes are done at the right time.
2. Data capturing and analysis. Have history of breakdowns in order to make it easy for the next Artisan to look at.
3. They can start by implementing discipline; let people take responsibility for their job. Not turning a blind eye when people don't perform.
4. Get the people to do, what they are supposed to do, not what they want to do.
5. By teaching the Operators how to solve minor problems and understand their duties according to Ford Production Systems.
6. By crediting Operators for job well done.
7. Maintenance to refrain from doing quick fix.
8. By recording all their lost time correctly and working on the problem areas.
9. Employee motivation (listen to shop floor concerns and don't try to avoid them).
10. Area managers must avoid giving ambiguous work instructions.
11. Have the people who work/operate machines involved in maintenance of machines.

The respondents feel that the management turns a blind eye when things go wrong. This could be the reason why employees need motivation because they perceive that the management does not listen to them. They suggest that the operator should solve

minor problems. This will reduce the time spent waiting for an artisan just to put the machine back to sequence.

They also believe that not all the time is recorded correctly, therefore that could be the reason for unidentified losses on the performance efficiency graph. It is always important to ensure that there is clear communication either bottom-up, top-down or horizontally. It is clear that there is a communication breakdown between the management and employees as the employees suggest that the management should avoid giving ambiguous work instructions.

Table 5.12 below is the summary of the respondents' opinions about quality in their workplace. There are also suggestions on how the company can improve its product quality.

The respondents suggest that the setters should be disciplined when changing the tool. They must check five parts after tool change as stipulated in a dynamic control plan. They believe that when there is a quality concern the machine producing a quality defect should be stopped and be fixed immediately.

Table 5.12: Respondents' opinions on how the company can improve quality.

SECTION E: QUALITY RATE

How can the company improve its quality?
1. Do the checks. Check five parts after tool changes.
2. Stop machines when quality concerns arise and fix problem immediately.
3. Keep machines clean. Preventive maintenance to be done on time.
4. Follow one quality standard not double standards.
5. By making sure that there is a quality inspector in each line at whole working hours.
6. Train Operators and Artisans about quality issues.
7. Stop overruling Team members when it comes to quality issues or concerns.
8. Good processes are in place just the individuals should respond more precise on their activities in carrying out their daily tasks.
9. If all of us do what we must and follow the procedures and Single Point Lessons (SPL) we will improve quality.
10. Motivation is needed, trust and believe on your workers. Quality should be everyone's responsibility.
11. Members have to adhere to gauging frequencies and to report any concerns when in doubt.

Preventive maintenance should be done on time and regular cleaning schedules should be introduced in order to ensure cleanliness of the machines. When the

machines are not cleaned regularly they can contribute to poor quality: for instance, when there is swarf (metal chips) between the clamps it could cause machine to cut skew. Therefore by keeping the machines clean, quality can be improved.

They also believe that there are different quality standards that are being followed in the company. They believe that they are overruled by their supervisors when raising concerns. They also believe that there is a need to train operators and artisans on quality issues and on how to identify defects. They suggest the use of SPL to improve quality. Some also believe that there are good processes in place: individuals need to start using them.

Table 5.13 below is the summary of the respondents about TPM and how the company can improve it:

The respondents believe that the planned maintenance is not done properly but is just a tick on a piece of paper. The reason for this could be the fact that they also feel that there should be spares available before the machine is booked for maintenance. At present they feel it is a matter of "go and look and see what is wrong, then we will make a plan later". This is frustrating the artisans as they consciously know that the machine is wrong but they cannot fix it because they do not have spares.

Table 5.13: Respondents' opinions on how the company can improve Total Productive Maintenance.

SECTION F: TOTAL PRODUCTIVE MAINTENANCE

How can the company improve its total productive maintenance?
1. PM's should be done properly and not be just a tick off on a piece of paper.
2. Get spares before the machine is booked for PM's.
3. Can be useful if is used right.
4. Having a technical person in charge of maintenance instead of production person.
5. Do more training and implement training in work area (on the job training).
6. Implementation of current processes to be enforced.
7. Regular feedback from all concerned.
8. Ensure that there are always spares available. When there is a problem fix it properly the first time.
9. Effective PM's and stick to scheduled PM's
10. Effective cross-functional teams should be formed.
11. Have standards in place to monitor how effective the artisans are in performing their duties.

There is a general belief that there is no regular feedback from supervisors and management when things go well or badly. There should be a process of monitoring effectiveness of work done by artisans.

The respondents also feel that there are processes and programmes in place but these are not implemented properly. Therefore they recommend that the company should enforce the implementation of the current processes.

Table 5.14 below is the summary of the respondents' opinions on the training they have received and how the company can improve it:

Table 5.14: Respondents' opinions on how the company can improve training and understanding.

SECTION G: TRAINING AND UNDERSTANDING

What do you think about the training you have received in the company?	**How can the company improve the training?**
1. Training was good, but could be better utilised in the work area.	1. Show the team members how the parts work and what is needed.
2. Gave me a broad understanding of production process and what the company wants to achieve.	2. Train the employees about FAR and FRACAS, and make them aware of how it works.
3. Very good - they must just learn the implementation of it.	3. Have qualified people give the training and send the people who actually excel in their work.
4. Less training given to artisans even if they attend training they are not given a chance to practice what they lean from training.	4. Do more on the job training.
5. The training is good, but when you want to implement what you've learned there's always some excuses why it won't work.	5. Training must be updated regularly.
6. Excellent. Keep training. Keep empowering for the future.	6. By sending the people who give training for facilitator training.
7. The training I have received at Ford will be able to help me to do my job effectively.	7. Sending or get someone who is the specialist on the field to train others.
8. Just a lot of safety training.	8. There's nothing to improve, only the attitude of the employees.
9. Training makes your performance more precise on every duty you have to carry out.	9. By providing relevant training to workers for e.g.: if a new machine is installed one operator, one setter, one fitter and one electrician from the department should be sent on proper training for the new machinery.
10. It works to a certain extent, but there is a lot of red tapes in terms of freely implementing and applying your knowledge.	10. Check what is needed to improve the morale of people.
11. Very informative.	11. By getting equipment relevant to the skill and follow up is required.

In short, those that have received training are positive that the training is good and has helped them to do their jobs better and more efficiently. There are still those who believe that for them training does not exist.

It is well known across the company that the team leaders are afforded more time for training compared to the artisans. Artisans are expected to maintain the machines when the lines are on short time, while team leaders are receiving training. Therefore it was expected that there would be different views about training existence.

One of the recommendations is to train trainers for them to deliver the training more effectively. It was suggested having qualified people giving the training or training the most experienced and excellent people in their jobs to be trainers.

It was also recommended that most training should be on-the-job training rather than classroom training and the training material should be updated regularly.

5.2.3 Task Team

A group of people was brought together to discuss what they feel is the cause of low machine uptime and how it can be improved. The group consisted of one millwright practising as an electrician, one fitter, one team leader, with the FTPM coordinator taking the lead.

The findings from the task team are in a form of SWOT analysis as indicated in table 5.15 below:

The observation from the task team's report is that there are programmes in place and these programmes are actually the company's strength because most of the companies struggle to have these programmes in place.

It is interesting that the weaknesses are actually the programmes that are in place but are not being used properly. For instance, one of the weaknesses is a lack of data collection and data analysis. The TEM system should be used to collect data and FRACAS and FAR's are used to analyse the problems and get to the root cause. The

FRACAS system is the system of minimising components that are not suitable for Ford machining lines, components that fail frequently.

Table 5.15: SWOT analysis of the current of maintenance operating system at Ford.

Strength	**Weakness**
• Crankline maintenance alarm • Visibility of artisans (workshop on line) • TEM system • Visual PM's (number the task on TEM reminder and PM's) • Autonomous maintenance system • FRACAS system • FAR PROCESS • 5's PROCESS • PD Maintenance system	• Maintenance tracking (data collection) • Data analysis • Departmental meetings (maintenance – communication) • PM updates: Running PM Down time PM • Hand-over procedure • Artisan training • Lack of ownership • Remuneration (compensation) {**HR**} • Not in permanent fix (too much quick fix) • Fixing of broken parts • Repair parts do not have 'OK' tags. (unable to tell if parts are working) • Skills gap between artisan and technician • Process conformation concerns are not transferred to line CCAR • Toolroom manning (PM's) – maintenance planning • Breakdown response time
Opportunities	**Threat**
• Artisan training operator to improve Autonomous Maintenance • Different shift patterns for artisans and production • Weekly planning for breakdowns and PM/ work for artisans • Inventory list in workshop with store item numbers • MIN/ MAX non consumables • Split stores (new and repair parts) • Test bench in workshop • Artisan projects (continuous improvement) • PM proposal • Rotation of artisan – by line	• Artisan turnover (fitter, electrician & technician)

The system fails at a point of follow-up to the vender, repairing of the components and actually minimising these components in the system. The main reason for this is the lack of reliable engineers in the plant. Because the plant was going through a difficult time, these jobs were made redundant. Now the need is evident and the company needs to make a decision whether to reopen these jobs or share the responsibility with the current workforce.

The opportunities are derived mainly from the weakness: for instance, one weakness identified is lack of ownership and the opportunity is to give artisan projects (continuous improvement). If the artisans were to take ownership of their equipment, continuous improvement will start creeping in and eventually becomes a culture.

Table 5.16 is the summary of findings when the task team was involved in block line:

Table 5.16: Findings of the task team.

Findings of the task team

Current situation	**Analysis / Root causes**
1. Poor PM completion	1. Not enough time to complete PM's Artisan skills Number of artisans PM content
2. Lack of data collection and analysis	2. Updating of PM's on TEM Failure Analysis Report not filled in properly FRACAS not followed
3. Poor handover	3. No communication between shifts (coordinators & artisans)
4. Lack of spares	4. No spares identification in maintenance cribs No spares coordinator – no spares control QAD (material requisition programme)
5. Poor work order completion (paper work)	5. Artisans not completing w/orders properly Poor breakdown description Poor capturing of data in TEM
6. Quick fixes	6. Lack of spares available Production not understanding the severity of quick fixes on the machines
7. Skills gap between artisans (Setters, Fitters, Electricians and Technicians)	7. Artisan turnover Lack of cross or up skills
8. Lack of ownership (artisans and operators)	8. No accountability
9. Toolroom not involved during PM planning	9. Toolroom manning
10. Poor autonomous maintenance completion	10. Team leaders not taking responsibility Too many pending open concerns
11. Lack / poor fault finding	11. Artisans training Lack of drawings

The task team was given an opportunity to make amendments to the current maintenance system and implement the proposed maintenance system in block line. The first step was to introduce the team to the management and team in block line so that everyone understands the involvement of the team to the line. The task team did not only look at the machine related data, the team also came up with the findings summarised in table 5.16.

The key issues from the summary of the task team are very similar to the findings from the questionnaire survey. The table is a clear indication of what the finding was and what was observed as the main issues: for instance, a lack of spares, no spares coordinator, no spares identification in maintenance cribs and the material requisition programme is not user-friendly.

5.3 TEST FOR RELIABILITY

When testing for reliability, questions are asked of the same people, but on two separate occasions. Responses for the two occasions are correlated, thus providing an index of reliability (Collis & Hussey, 2003:186).

In order to test the reliability of the feedback from the questionnaire, a group of people was brought together to discuss what they consider the cause of the low machine uptime to be and suggestions on how can it be improved. The following questions were asked in the questionnaire (ref. table 5.5):

- Does the machine often stop for idling and minor stops?
- Does the machine often stop for dirty sensors?

This is basically the same question as the one in the table. For both questions
68 percent of the respondents answered positively.

Similarly, the following questions were asked in tables 5.8 and 5.9 respectively:

- Are people encouraged to improve their knowledge and skills at work?
- Is there an opportunity for people to acquire and enhance skills and experience and develop their full potential?

The respondents' response rate was exactly the same: 50 percent of the respondents strongly agreed, 13 percent were uncertain and 37 percent strongly disagreed. This confirms the integrity of the response data.

The respondents were also asked to comment on what they think could be done to improve availability, performance efficiency, quality rate, total productive maintenance, training and understanding in section I of the questionnaire. This question was also used to test whether the answers correlated.

Finally, a group of people was brought together to discuss what they feel the cause of low machine uptime is and how they believe it can be improved. The group consisted of one millwright, one fitter and one team leader. These people were strategically selected in order to represent the targeted sample for the questionnaires. The findings from the task team did not contradict the findings from the respondents.

The responses indicated that they had given the matter some serious thought and therefore the scale was considered to be reliable

5.4 SUMMARY

In this chapter, the empirical results were reported. More specifically, the general perceptions of Overall Equipment Effectiveness, Total Productive Maintenance, training and human factors in design for maintenance were highlighted. In addition, the findings of the task team were discussed.

In the next chapter, chapter six, the summary, conclusions and recommendations will be presented. Managerial implications of these empirical findings for Ford Struandale Engine Plant will also be discussed.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

In chapter five the researcher discussed the findings from the empirical study. The aim of chapter six is to combine data from the literature survey, Ford literature and the empirical study in order to answer sub-problems and eventually the main problem.

The aim of chapter five was to highlight the main findings of the research then analyse and interpret them. The empirical findings of both the qualitative and quantitative research were compared to the theory in order to identify how the Ford Struandale Engine Plant is performing with respect to Availability, Performance Efficiency and Quality. In addition, the focus is also to highlight how effectively other Ford tools like Ford Total Productive Maintenance, Human factors and Quality factors are integrated to improve OEE. The company literature indicated that these programmes and systems are in place but the question was how effective they are.

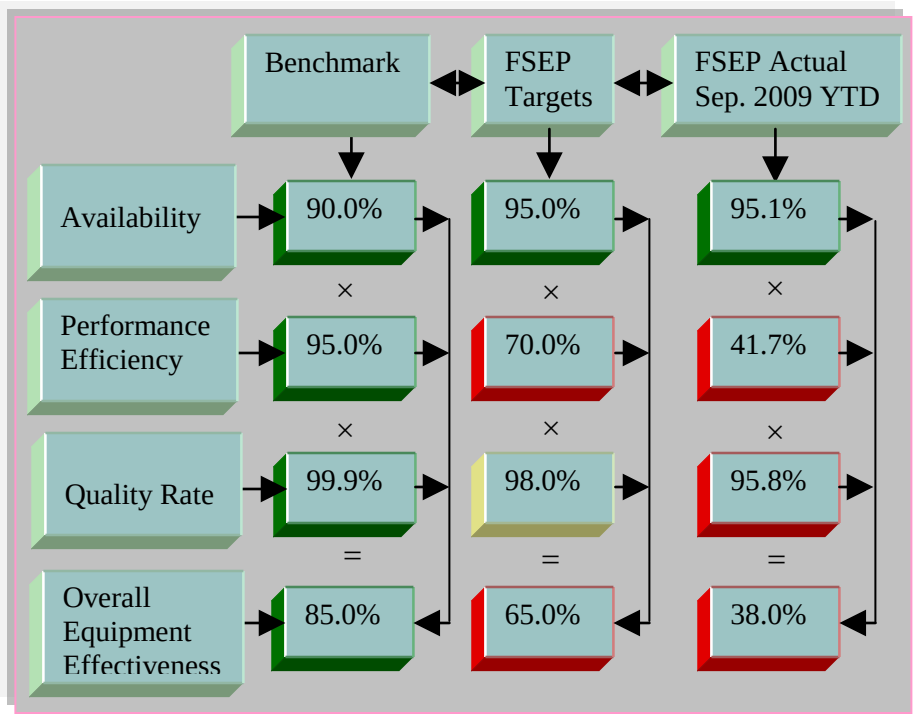
The purpose of this chapter is to draw conclusions from the literature and the empirical finding about the OEE performance of Ford Struandale Engine Plant and to recommend how Ford Struandale Engine Plant can improve the Overall Equipment Effectiveness.

6.2 ANALYSIS OF THE RESEARCH FINDINGS

The findings from the general literature, FSEP literature and empirical survey are amalgamated to draw a conclusion. Figure 6.1 below is the summary of the findings with regards to Overall Equipment Effectiveness. Blockline was used because it was a constraint line at FSEP. It was highlighted in chapter two that it is always important to calculate an OEE of the constraint operation.

Figure 6.1 below depicts the summary of OEE benchmarked on world class manufacturing standards (http://www.oee.com/world_class_oee.html), FSEP targets and FSEP actual results (W:\GROUP\FPS\5.Management\2009 Policy Deployment).

Fig. 6.1: Summary of overall equipment effectiveness



Source: http://www.oee.com/world_class_oee.html
W:\GROUP\FPS\5. Management\2009 Policy Deployment

According to the literature, word class OEE is 85 percent or better as indicated in figure 6.1 (http://www.oee.com/world_class_oee.html). FSEP targeted an OEE of 65 percent for blockline. The actual OEE achieved year to date is 38 percent.

The OEE factors are analysed below:

6.2.1 Availability

Availability can be defined as the ratio of full functional equipment to all reparable (functioning and nonfunctioning) equipment within a given period of time (Gotoh, 1991:9). For most equipment, the three major obstacles to availability are:

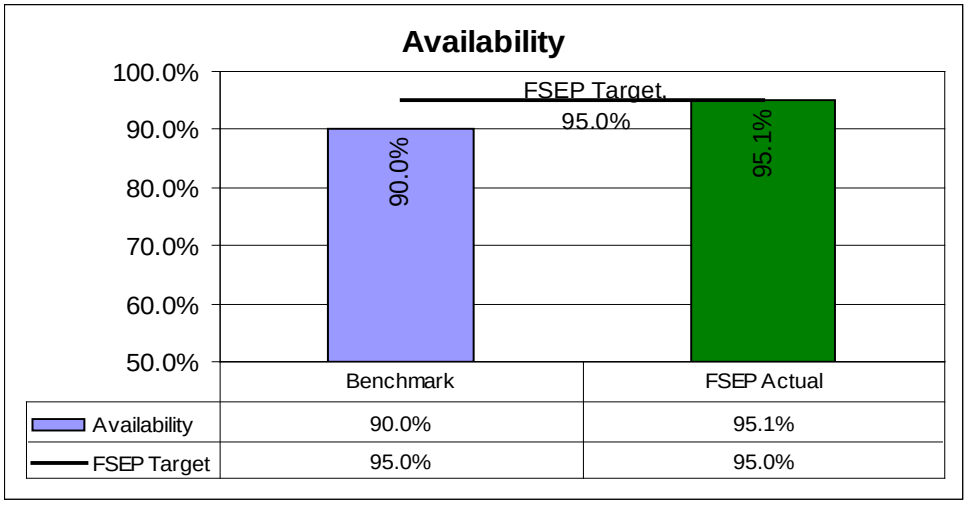
- Breakdowns
- Downtime for maintenance

- Changeovers

Availability is the amount of the time when the equipment was needed to be run, that it actually was able to be run (http://www.fps.ford.com/learningeventslearningbew .html).

Chart 6.1 below is the availability analysis chart:

Chart 6.1: Availability



Source: http://www.oee.com/world_class_oee.html
W:\GROUP\FPS\5. Management\2009 Policy Deployment

The world class manufacturing benchmark availability is 90 percent or above (http://www.oee.com/world_class_oee.html). Chart 6.1 above indicates that FSEP for the year 2009 targeted an availability of 95 percent. This is a stretched target when compared to the world class manufacturing target of 90 percent. Year to date FSEP is running at 95.1 percent availability. FSEP met its target and exceeded the benchmark target by 5.1 percent. This simply means that at FSEP the machines are not available for 4.9 percent of the time when scheduled to run.

The Performance Efficiency at FSEP is 95.1 percent which exceeds the world class benchmark standard. Although it is 95.1 percent according to the empirical survey and respondents, there is still room for further improvement. Recommendations for

further improvement are made from empirical survey and respondents' opinions in the recommendation section of this chapter.

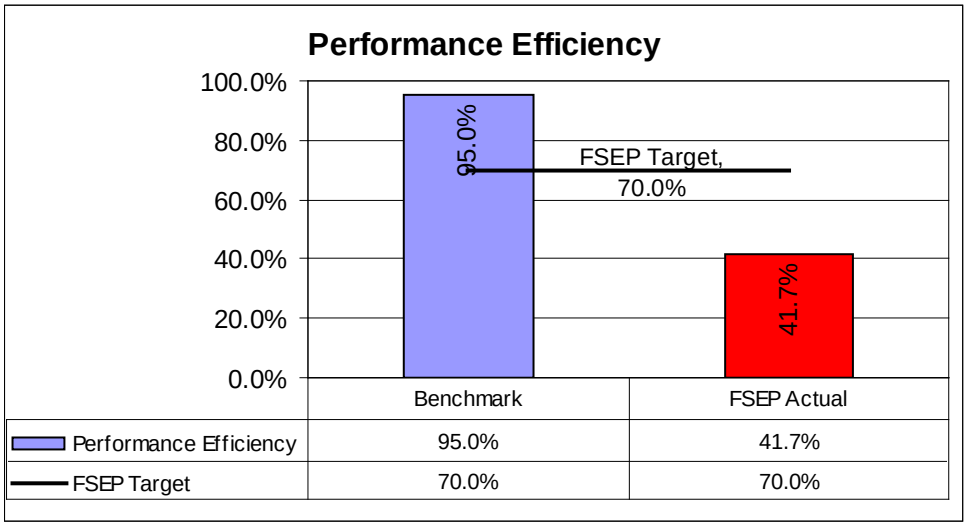
Generally FSEP is performing well as regards availability and 95.1 percent is better than world class world target of 90 percent.

6.2.2 Performance Efficiency

Performance Efficiency is a factor that measures how well the machine is being run when it is available. Running at less than optimum cycle time has a major impact on this factor as does a "blocked and/or starved" process (http://www.fps.ford.com/learningeventslearningbew.html). According to Davis (1995:35), percentage performance is the ratio of what was actually produced in a given time over what would have been expected to be produced in a given time.

Chart 6.2 below is the Performance Efficiency analysis chart:

Chart 6.2: Performance Efficiency



Source: http://www.oee.com/world_class_oee.html
W:\GROUP\FPS\5. Management\2009 Policy Deployment

The world class manufacturing benchmark performance efficiency target is 95 percent or above (http://www.oee.com/world_class_oee.html). Chart 6.2 above indicates that for the year 2009 FSEP targeted Performance Efficiency of 70 percent. Year to date FSEP is running at 41.7 percent Performance Efficiency. This indicates

that the company forecast a “below world class performance efficiency” from the beginning. FSEP could not meet its less stringent target of 70 percent Performance Efficiency. This simply means that the line is producing only 41.7 percent of its capacity.

This is a very poor performance for a company striving to be a world class manufacturing company. FSEP could not even reach 50 percent of the targeted world class Performance Efficiency.

The main reasons for poor Performance Efficiency, according to the survey, are:

- Machinery often stops for dirty sensors (68 percent agree).
- Certain machines have a longer cycle time than the design cycle time (76 percent agree).
- When calculating efficiency the time allocated does not add up to 100% (84 percent agree).
- There are no regular cycle time studies being conducted on the machinery to ensure they still at their designed cycle time (39 percent agree).

When autonomous maintenance is not being carried out on daily basis the machines will then stop for unnecessary reasons like misalignment, low hydraulic levels and dirty sensors. This was acknowledged by the respondents as they indicated that 68 percent of the time machines stop for dirty sensors as indicated in table 5.5.

The task team indicated the there is lack of data collection and analysis in table 5.15. This was also proven with 76 percent of respondents believing that when calculating Performance Efficiency, the time allocated does not add to 100 percent as indicated in table 5.5. When a machine is down, an operator will call an artisan. The artisan will fix the machine. While the artisan is fixing the machine, the operator then leaves the workstation. When the artisan has finished, s/he has to wait for the operator. When the machine is available the operator is not there to operate the machine. The time while machine is waiting for an operator is not logged. This then results in unidentified losses that cannot be accounted for.

The team leaders need to make sure that they control the operators and that they can account for the time they have not logged. This is also an indication of dysfunctional FTPM. FTPM encourages the operators to assist the artisans in order to achieve transfer of knowledge. This will assist the operators to understand the importance of carrying out the autonomous maintenance tasks.

Performance Efficiency also indicated that there is lack of commitment from top to bottom. The production personnel do not show commitment as they cannot produce at high efficiencies when machines are 95.1 percent available for production. On top of that they cannot account for the discrepancy when calculating efficiency. Management forecast that they would not better the world class performance efficiency of 95 percent. Instead of implementing countermeasures, they targeted low 70 percent Performance Efficiency. Still FSEP did not meet the 70 percent Performance Efficiency target. Any company striving to be the best in its class cannot afford not even meeting less stringent targets.

Performance Efficiency hinders the Overall Equipment Effectiveness of FSEP. The areas of concerns are minor stoppages and longer cycle times. It was highlighted during the literature review that the major two big losses that affect performance efficiency are idling and minor stoppages; and reduced speed losses. These findings indicate a correlation between the literature and the empirical results.

FSEP management needs to focus more on Performance Efficiency in order to improve OEE performance by eliminating the minor stoppages and fixing the machines with longer cycle times. The production employees should be made accountable for not producing while machines are available to produce. Actually employees should be held accountable at all levels.

At FSEP data should drive business decision-making and be used to monitor trends, prioritise issues and confirm the effectiveness of problem prevention, resolution and continual improvement programmes. Management should identify opportunities for growth and encourage and support employees in their efforts for continual improvement.

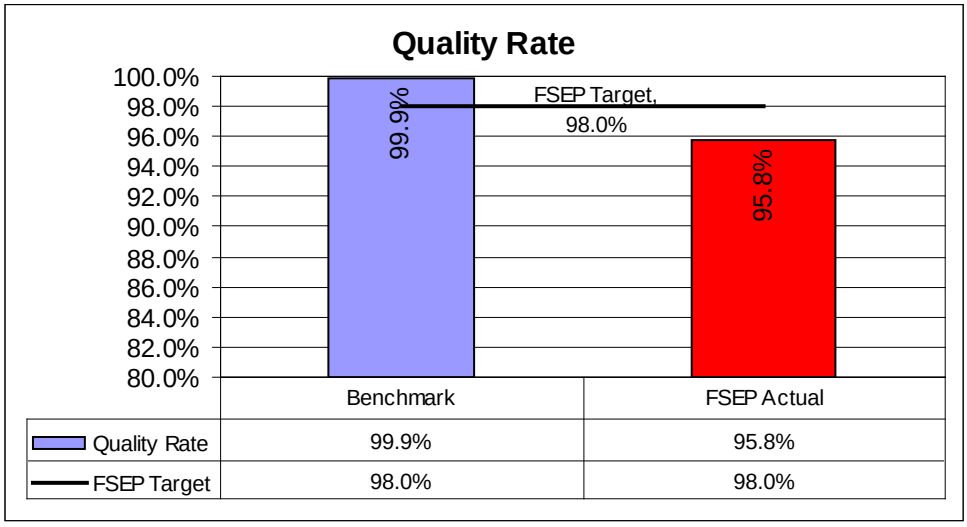
Performance efficiency of 41.7 percent is very poor for a company striving to be word class. This is why FSEP has a poor OEE of 38 percent.

6.2.3 Quality Rate

Quality Rate is basically first run capacity or first run quality. It is the number of good parts minus defective parts produced without spending non-value added labour (defective parts comprise scrap and re-worked parts including those used to set up the line) http://hub.fmcsa.Ford.com/pe/FORD/FordStructure/ASPPages/FTPMpackages .asp.

Chart 6.3 below is the quality rate analysis chart:

Chart 6.3: Quality Rate



Source: http://www.oee.com/world_class_oee.html
W:\GROUP\FPS\5. Management\2009 Policy Deployment

The world class manufacturing benchmark quality rate is 99.9 percent or above (http://www.oee.com/world_class_oee.html). Chart 6.3 above indicates that FSEP for the year 2009 targeted a quality rate of 98 percent. Year to date FSEP is running at 95.8 percent quality rate. FSEP did not meet the targeted quality rate. The target was 4.1 percent below that the world class benchmark of 99.9 percent.

The main reasons for the poor quality rate according to the survey are:

- Only 71 percent of respondents agree that FSEP records the startup rejects;
- Only 82 percent of respondents agree that FSEP has measures in place to protect the customer and
- Only 76 percent of the respondents agree that FSEP continuously strives to improve its products and processes.

In terms of scrap and rework, knowing the size of the loss is not enough. To improve performance, manufacturers also need an accurate indication as to the source of the loss (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf).

According to the empirical survey, 95 percent of the respondents agree that the company records the scrap and rejects as indicated in table 5.6.

The setting after changeover or tool change need to be perfected to reduce the startup rejects. This can be achieved through Single Point Lessons and by the use of tool masters when setting the tools.

Through continuous improvement FSEP needs to improve quality rate. Continuous improvement needs the involvement of everyone in the organization, from shop floor workers to top management (International Journal of operations and Production Management, 1999:1190). Companies achieve quality not by checking results or screening out defects, but by ensuring that no defects are created by upstream processes. Quality maintenance is a specific method for building in quality through processes and equipment (Suzuki, 1992:86).

A quality rate of 95.8 percent is not good enough; therefore FSEP needs to concentrate on improving quality as poor quality could damage the buyer confidence and affect the brand image.

6.2.4 Other Factors

Other factors that were considered by the researcher include Total Productive Maintenance, training and understanding and human factors. The findings from the study were as follows:

(a) Total Productive Maintenance

The goal of TPM is to effect fundamental improvement within a company by improving worker and equipment utilisation. According to Nakajima (1988:54), in order to eliminate the Six Big Losses, people's attitudes must first be changed and their skills increased. Increasing their motivation and competency will maximise equipment effectiveness and operation. Such improvements in the quality and functioning of equipment and in one's mental outlook are essential to fundamental corporate improvement. Unless top management takes the lead by seriously tackling the issue of changing people's attitudes and increase their skills, however, the necessary transformation in attitudes, equipment and the overall corporate constitution will not progress smoothly (Nakajima, 1988:54).

The elimination of Six Big Losses will result in improved availability, performance efficiency and quality rate. The Six Big Losses directly affect the three factors of OEE as indicated in figure 6.1 below:

Fig 6.2: Six Big Losses versus OEE factors

OEE Factors	**Six Big Losses**
Availability	Breakdown losses
	Setup and adjustment losses
Performance Efficiency	Idling and minor stoppage losses
	Reduced speed losses
Quality Rate	Startup rejects
	Production rejects

Source: http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf

The objective of Ford Total Productive Maintenance (FTPM) is to maximise the overall effectiveness of the plant facilities, equipment, processes and tooling through the focused efforts of SG Activities directed at elimination of the Seven Major Losses (http://hub.fmcsa.Ford.com/pe/FORD/FordStructure/ASPPages/FTPMpackages.asp).

The majority of respondents (45 percent) strongly disagree that the maintenance operating system has been communicated to plant employees, while 18 percent are uncertain. This could cause misunderstandings as the respondents are not aware of the current maintenance operating system. The plant management expects certain level of performance, assuming that everyone understands the current maintenance operating system. This could cause a conflict of interests as 45 percent of respondents disagree that there are detailed roles and responsibilities and levels of authority for all maintenance personnel that are well-defined, communicated, updated and understood plant-wide (Refer to table 5.7).

Therefore when a programme is not well communicated and there are no clear roles and responsibilities, the FTPM is doomed to fail.

According to table 5.15 the task team also indicated that there is a lack of data collection and analysis, lack of ownership and lack of spare parts. All these are indications of a dysfunctional TPM programme.

Although FTPM system is theoretically good, the application at FSEP lacks fundamentals and need to be addressed.

(b) Training and understanding

A company implementing TPM in order to improve OEE must invest in the training that will enable employees to manage their equipment properly. In addition to training maintenance techniques, operators must also sharpen their conventional operation skills (Nakajima, 1988:96).

FSEP has provided training that enables employees to manage their equipment. This training involves Basic Equipment Wellness, Autonomous Maintenance, 5S, Value

Stream maps, Safety, Ergonomic and Environmental training (W:\GROUP\TRAINING\Training Records).

Yet the respondents believe that FSEP is not doing enough in giving appropriate training to support maintenance processes. Only 45 percent agree that the facility does provide appropriate training to support maintenance processes as indicated in chart 5.12. The reality is that the majority of the time artisans are not involved in training because training takes place when there are breakdowns and their skills are required. During non-production days they are expected to do planned maintenance on their machines.

The task team also highlighted the fact that artisan training and the skills gap between artisans and technicians are weaknesses for the company as indicated on table 5.15.

Based on the responses to the questionnaire and one-on-one discussions with FSEP employees, the researcher's findings are that the FSEP does not conduct sufficiently effective training at artisan and setter level that will support the FTPM and lead to improved OEE for the plant.

6.3 ADDRESSING THE RESEARCH PROBLEMS

The main problem mentioned in chapter one was: **What are the underlying factors that are hindering the improvement of Overall Equipment Effectiveness at Ford Struandale Engine Plant?**

The purpose of the study was to address the primary objective which is to identify how Overall Equipment Effectiveness (OEE) at Ford Struandale Engine Plant can be improved by investigating factors that influence OEE. The researcher provides answers to the main problem mentioned above by answering each of the sub-problems.

In order to answer the main problem, the five sub-problems will first be addressed:

i) What the literature reveals in terms of how to calculate OEE

In chapter two section 2.2 it was stated that according to Davis (1995:37), Overall Effectiveness is a measure of all three of these factors (percentage availability, percentage performance, percentage quality) and, although it is not strictly a percentage, it is usually represented in percentage terms and is calculated as: **overall effectiveness = % availability × % performance × % quality**

It was also revealed that the Ford Struandale Engine Plant uses the same calculation to calculate OEE as stated in chapter three section 3.2.1 (e) and referred to in figure 3.3. FSEP calculates OEE the correct way.

ii) What the contributing factors are that influence OEE

- Availability
- Performance efficiency
- Quality rate

According to Bernstein (2005:101), **OEE = availability rate × performance rate × quality rate**. The availability rate expresses losses due to unplanned stoppages, the performance rate expresses losses due to machine performance lower than ideal or standard operating rates and the quality rate expresses losses due to rejects and reworks.

FSEP literature revealed that the three factors which comprise the Overall Equipment Effectiveness (OEE) all have an effect on how well the equipment and processes perform to their ideal design levels. The value is in focusing on these factors to locate waste (http://www.fps.ford.com/learningeventslearningbew.html). FSEP uses Overall Equipment Effectiveness (OEE) to measure equipment losses as indicated in figure 3.3.

Figure 6.1 indicates FSEP performance in all three factors of OEE. The Overall Equipment Effectiveness of FSEP is 38 percent. This is a poor performance for any plant striving to be world class. World Class Manufacturing companies run at OEE of 85 percent or better (http://www.oee.com/world_class_oee.html) as indicated in table 2.1 in chapter two.

iii) What the impact of the Six Big Losses is on OEE

OEE can be broken down further to specify more accurately the factors of OEE. One such model is the Six Big Losses:

- Breakdown losses
- Setup and adjustment losses

} Availability

- Idling and minor stoppage losses
- Reduced speed losses

} Performance Efficiency

- Startup rejects
- Production rejects

} Quality Rate

OEE provides the means to evaluate the production process by measuring the effective utilisation of the capital assets. The goal of OEE is to eliminate the Six Big Losses. The relationship between the six process losses and OEE is shown in table 2.2 (http://www.shumaonline.com/files/The-Six-Big-Causes-of-Lost-Production-Time.pdf). In other words, OEE addresses all losses caused by the equipment not being available when needed due to:

- Breakdowns;
- Set-up and adjustment losses;

Not running at the optimum rate due to:

- Reduced speed;
- Idling and minor stoppage losses;

Not producing first pass quality output due to:

- Defects and rework; and
- Start-up losses (Gupta, Tewari and Sharma, 2006).

The Six Big Losses are described as formidable obstacles to Overall Equipment Effectiveness (Nakajima, 1988:14). Figure 3.3 depicts how the Six Big Losses affect each OEE factor.

iv) What is the Ford Struandale Engine Plant's performance on each of these aspects?

- Availability
- Performance efficiency
- Quality rate

Table 6.1: Ford Struandale Engine Plant OEE findings.

OEE Factor	Blockline
Availability	95.1%
Performance	41.7%
Quality rate	95.8%
Overall OEE	38.0%

Source: http://www.oee.com/world_class_oee.html

Table 6.1 depicts the Ford Struandale Engine Plant performance on Availability, Performance Efficiency and Quality rate. The Availability of 95.1 percent is good, is the best in its class. The Performance Efficiency of 41.7 percent reflects a bad performance. More management focus on improving Performance Efficiency is urgently required. A Quality rate of 95.8 percent is better but, can be improved.

Empirical results indicated the following:

Firstly, respondents indicated that the major reasons for good machine availability are:

- The machine availability is visible and understood by everyone
- Every breakdown is captured and trended
- The company has a changeover procedure

Secondly, respondents indicated that the major reasons for poor performance efficiency are:

- Machinery more often stops for dirty sensors
- Certain machines have longer cycle times than the design cycle time

Finally, respondents indicated that the reasons for better quality are:

- The company records the rejects, scrap, and assembly returns

- The company records the startup rejects

v) The impact that training has on OEE at FSEP

- What literature reveals about training
- What people at Ford Struandale Engine Plant feel
- What Ford Struandale Engine Plant has done

Technical training in equipment maintenance and operation identifies the specific knowledge, skills, and management abilities people should have so that right training programmes can be designed to instill them (Bernstein, 2005:63).

According to Shirose (1992:138), the following skill-related conditions are absolutely necessary for successful TPM:

- Equipment operators should possess the training and skills to carry out autonomous maintenance and to understand their own equipment
- Maintenance department staff should possess the training and skills to carry out maintenance and repairs and to smoothly implement preventive maintenance.

A company implementing TPM must invest in the training that will enable employees to manage their equipment properly (Nakajima, 1988:96).

FSEP has provided training that is relevant in order to improve Overall Equipment Effectiveness. This training involves Basic Equipment Wellness, Autonomous Maintenance, 5S, Value Stream maps, Safety, ergonomic and environmental training. According to the survey not everyone had the chance to attend this training (W:\GROUP\TRAINING\Training Records).

The survey concluded by the researcher revealed that there are two distinct attitudes towards training:-

- Team leaders feel that the company is doing exceptionally well in terms of training its work force,
- Artisans, however, feel that the company is not doing enough to train or improve the skills of its work force.

This is probably due to the fact that team leaders have Fridays available for training while artisans have to do maintenance on the machines. This is the reason for the split.

vi) Ford Struandale Engine Plant has programmes to improve OEE.

These programmes include:

- Ford Total Productive Maintenance
- Human factors
- Quality factors

The question is whether they are effective.

These programmes have been discussed in chapter three, FTPM in section 3.2, Human factors in section 3.3 and Quality in section 3.3.

A survey was conducted on section F for FTPM, section G for quality and section H for Human factors of the questionnaire. The survey revealed the following:

Ford Total Productive Maintenance

The respondents believe that artisans provide support to operators. They are actually using the operators as the first line of defence when there is a problem on the machine because the operators see the symptoms before the machine actually stops. Operators conduct daily checks on their machinery and equipment they operate. Autonomous Maintenance ensures that operators do this on a daily basis.

The artisans are conducting Preventive Maintenance. According to the feedback from the respondents and the task team there is a lack of spares when doing PM. Therefore some of the PM is just a tick on the box and no corrective action has been done.

The majority of the respondents do not believe that data is collected and analysed to eliminate losses. The majority of the respondents also believe that people are encouraged to make and implement suggestions in the plant.

Generally, the majority of the respondents still believe that there are fundamental processes that are not in place or being utilised to their full potential. OEE has not improved.

Therefore FTPM is not effective because FTPM has been designed to maximise equipment effectiveness (improving overall efficiency) by establishing a comprehensive productive maintenance system covering the entire life of the equipment, spanning all equipment-related fields (planning, use, maintenance,) and, with the participation of all employees from top management down to shop-floor workers, to promote productive maintenance through "motivation management," or voluntary small-group activities. TPM aims at maintaining the optimal condition of equipment and upgrading maintenance skills (Tsuchiya, 1991:4).

FSEP has implemented a task team that is currently looking at all factors that are causing the failure of FTPM. The team is used for transformation purposes, whereby the team will be together for two to three months for coaching in current maintenance processes. The team will be given projects to implement the lessons learned. Then the team will be split to implement the lessons learned on their individual lines and a new team will be assembled. In this way the continuous improvement cycle continues.

Human factors

The majority of respondents agrees that Ford management care for or looks after their employees' well-being. This is enhanced by the Employee Wellness Programme.

About 74 percent of the respondents acknowledge the fact that the Ford Motor Company encourages team work. This is also encouraged up to the shop floor through natural work group meetings. The human factors are generally effective based on the positive response form the respondents and the FSEP literature.

FSEP has implemented a licensing method for the critical safety training like ECPL training. The trainees must obtain a 100 percent pass mark before being declared competent.

Quality factors

The average response of 81 percent answered all the questions related to quality very positively. The majority of the respondents strongly believe that everything that is supposed to be in place for quality is actually in place.

There was a generally good response for quality: the figures on annexture E indicate good quality and figure 6.1 indicates a quality rate of 95.8 percent. The few concerns are due to the fact that they feel overwhelmed when there is a quality concern on their lines and they also feel that the line should be stopped immediately when there is a quality concern.

This concern contradicts the Ford quality policies and work instructions because according to chapter three of Ford's literature, the company stipulates that the work groups have the authority to stop the process when they see a defective process and fix it. Generally the quality factors are effective. This was also supported by the fact that annexure E indicated evidence of customer protection whereby the scrap rate increased but assembly returns decreased to zero returns.

In order to improve Quality factors FSEP is conducting training with team leaders every Friday. This training involves Statistical Process Control, First Time Through, Cost saving, problem solving tools (5 Whys, Ishikawa, A3, FAR), Basic Equipment Wellness, Autonomous Maintenance, 5S, FRACAS, Value Stream maps, Safety, ergonomic and environmental training (W:\GROUP\TRAINING\Training Records).

Unfortunately, due to operational requirements, it is not possible for artisans and setters to participate in such training as well.

6.4 CONCLUSION

The Overall Equipment Effectiveness of the Ford Struandale Engine Plant stands at 38 percent. Therefore, based on the findings of this research, the Ford Struandale Engine Plant is not a World Class Manufacturing company. The area of concern is the poor performance efficiency of 41.7 percent. Performance efficiency is the main cause of the poor OEE performance at the FSEP. The FSEP needs to improve its performance efficiency.

6.5 RECOMMENDATIONS

The following recommendations were made based on the data collected through the FSEP literature survey, the empirical survey and the feedback from the task team:

6.5.1 Availability

FSEP currently has an availability of 95.1 percent which is a very good performance and is world class. Management should congratulate the team on a job well done.

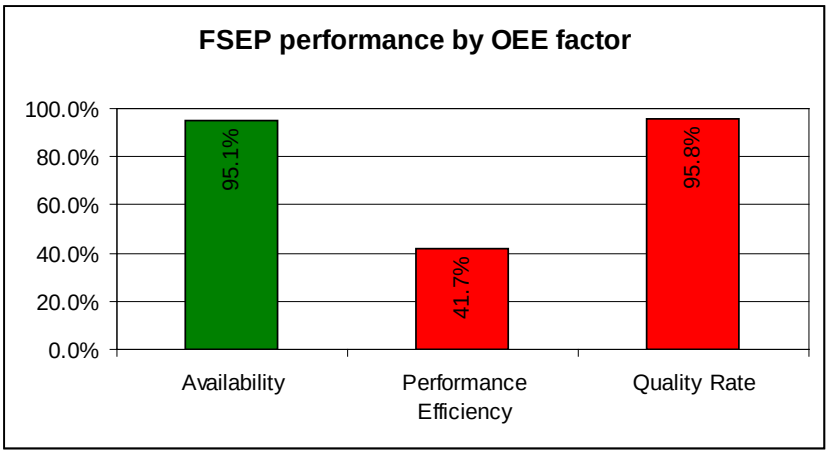
6.5.2 Performance Efficiency

In order to improve the performance efficiency rate of 41.7 percent the following recommendations are made:

- At the start of a shift the artisans should make sure all the critical sensors are wiped clean and are free of swarf and moisture. The operators should conduct their Autonomous Maintenance check to pick up any visual signs of abnormality such as empty hydraulic tanks or defeated interlocks.
- Full cycle time studies should be done, involving process engineers, setters, maintenance and operators in identifying the causes of the longer cycle time.
- If the machines are no longer capable of running at these cycle times, then the line capacity should be adjusted according to the new cycle times.
- Work groups should be trained about unidentified losses and the impact they have on performance efficiency.

Figure 6.4 depicts FSEP performance by OEE factors (Availability, Performance Efficiency and Quality Rate).

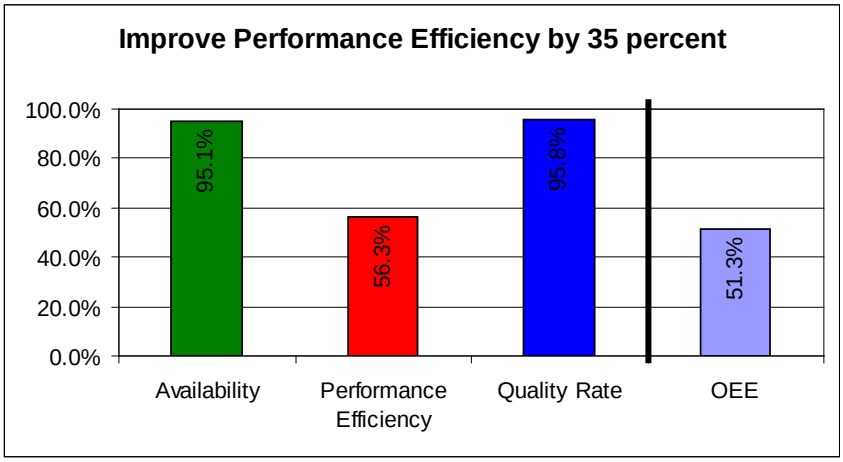
Chart 6.4: FSEP performance by OEE factor



Source: W:\GROUP\FPS\5. Management\2009 Policy Deployment

According to the chart above, Performance Efficiency is the major concern. The company should first start by improving Performance Efficiency because Performance Efficiency improvement will have much more impact than any other factor, for instance if the company were to improve Performance Efficiency by 35 percent:

Chart 6.5: Improve performance Efficiency by 35 percent



When performance efficiency is improved by 35 percent, OEE will be 51.3 percent as depicted in chart 6.5 above but, if FSEP improves availability to maximum as depicted in chart 6.6 below.

Chart 6.6: Maximum Availability

OEE will only be 39.9 percent, therefore any improvements either that performance efficiency will not have significant improvement on OEE.

6.5.3 Quality Rate

In order to improve the Quality Rate of 95.8 percent the following suggestions are recommended:

- The work groups including artisans, setters, team leaders and operators should be trained in the importance of pre-shift inspection.
- Artisans or setters should run at least five parts after fixing the machine or changing the tool. These five parts should be gauged to ensure good quality before running production at full capacity.
- The fact that the next operators are the customers must be enforced in order to ensure that they are getting quality components. The customers must feed back to the suppliers about any inferior quality or superb quality being received. When the operators are treating themselves as customers and suppliers, it will ensure that inferior components do not reach the customers.
- It is essential that team leaders involve the work groups when doing the A3 continuous improvement projects. The projects must be communicated to all the employees when completed and should state clearly the outcomes in terms of savings, quality improvements or morale boosting.

6.5.4 Other Factors

- It is recommended that the company should have a spares coordinator. This is the person who will ensure that the spares are available whenever there is equipment breakdown or when machines are scheduled for maintenance. The spares coordinator will also make sure that all the parts that require repairs are repaired and tagged with the OK tags.
- It is also recommended that the company rehire the Reliability and Maintainability Engineers as it is clear that there is a huge gap for analysing the data collected. The R&M engineers will analyse the data, use it for the purchasing of new machinery and reducing the components that are not suitable for Ford's application. R&M will be used to restore these commodity spares and also to complete the cycle of FRACAS.

- It is recommended that the company use the lessons learned from the formation of the task team to transform the rest of the employees involved in maintenance and production.
- As far as the training is concerned, it is recommended that the company should start aggressively up- or cross-skilling its employees or both, as technology is advancing. This will also contribute to a reduction of downtime as the operators need not wait for the artisan to sequence the machine or a fitter need not wait for an electrician to disconnect or connect a motor.
- It is recommended that for the new PUMA programme the company should electronically link (SCADA system) all its machines for data collection. The manual system currently being used is time-consuming and the reports cannot be made available at any given time. It is recommended that the Ford Struandale Engine Plant should look at the TRS system currently being used by Ford Australia for automatic reporting system. TRS is the Ford Australia in-house developed Total Equipment Management Reporting System used to improve the current reporting of the reports from the TEM system. Before the introduction of the TRS, Australia had the same problems as the FSEP is experiencing with the current TEM reporting system.

6.6 PROBLEMS AND LIMITATIONS

No major problems were encountered while conducting the research except for some of the selected respondents' lack of co-operation, specifically the artisans. Due to different shift patterns, some respondents were on night shift and did not return the questionnaires because they were encouraged to complete them when they had no breakdowns. Some demanded to be given time to sit and complete the questionnaires but, that was not practical as they cover production by attending to breakdowns.

The survey was limited to the Ford Struandale Engine Manufacturing Plant, located in Port Elizabeth. This does not include the Silverton Vehicle Assembly Plant, which is located in Pretoria. The empirical component of this study was limited to hourly employees, team leaders and artisans (electricians and fitters) of the Struandale Engine Plant.

In addition, the APQP and PPAP programmes were not discussed in detail in this research.

6.7 OPPORTUNITIES FOR FUTURE RESEARCH

A number of related issues could be addressed by further research. Some of these research issues are outlined below:

- This study should be done at other engine manufacturing plants in South Africa. The main aim of the study will be the trends in the behaviour of the organisations towards the implementation of TPM.
- Are there strategies for re-implementing TPM without losing the interest of the people that know that the company has already implemented TPM before?
- What is the main reason for the poor performance efficiency at FSEP?
- What is the TPM culture in the plants that have fully implemented TPM in South Africa?
- OEE improvement will be based on the Japanese principle of multiple, continuous small improvements. Therefore the findings of this study are not necessarily a closing of a chapter but the opening of investigating strategies for engaging management and union in assisting to improve OEE.

6.8 SUMMARY

The finding of this study indicated that the biggest single cause of poor Overall Equipment Effectiveness at Ford Struandale Engine Plant is poor performance efficiency.

If the Ford Struandale Engine Plant could change the current performance efficiency of 41.7 percent to the targeted value of 70%, the Overall Equipment Effectiveness target of 65 percent could possibly be met.

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QUESTIONNAIRE COVER LETTER

Research title: THE FACTORS THAT HINDER THE OVERALL EQUIPMENT EFFECTIVENESS AT FORD STRUANDALE ENGINE PLANT

Researcher: Sazile Qweleka
FTPM Coordinator: Ford Struandale Engine Plant.

Dear participant

I am currently busy with my Masters degree in business administration at the Nelson Mandela Metropolitan University (NMMU). I am working at Struandale Engine Plant as Ford Total Productive Maintenance (FTPM) Coordinator.

I am doing research on Overall Equipment Effectiveness (OEE) as the primary metric of Total Productive Maintenance (TPM). In order to gather information, I have decided, after observing the production efficiencies, downtime and machine availability of the plant to develop a questionnaire asking you your honest opinion on how you see things in the plant as indicated in the questionnaire. I will use the findings as part my research. The survey will be limited to personnel involved in production and maintenance from the two production area (engine component machining and engine assembly) of Struandale Engine Plant. Please note that the information collected will not be used against the organisation in any way and your response will be strictly confidential.

Therefore, I humbly request that you please complete the questionnaire, which is absolutely anonymous and return it to me by 20 October 2009. I thank you in advance for your highly appreciated contribution in this research.

Kind regards

Sazile Qweleka

QUESTIONNAIRES

SECTION A: BIOGRAPHICAL INFORMATION

Please fill in the circle that best applies to you.

What is your gender?

O Male

O Female

What is your age?

O 18 – 25 years

O 26 – 35years

O 36 + years

What is your current position?

O Team leader

O Artisan

What is your highest qualification?

O High school

O Diploma

O Degree

Years of service

O 0 – 1 years

O 2 – 5 years

O 6 – 10 years

O 11 – 15 years

O 16 + years

SECTION B: OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Please indicate the extent to which you agree or disagree with the following statements by marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	I do understand the overall equipment effectiveness of the machines in my work area.					
2	Operators collect data for their machines.					
3	I do understand the Seven Big Losses (breakdowns, minor stops, tooling losses, startup losses, etc).					
4	The company does identify and eliminate the various losses, then good production increases.					
5	OEE is used to prioritise the improvement opportunities and forming cross-functional teams to eliminate root cause of the loss.					
6	The company does have a changeover process.					
7	Plant leadership (union and management) are on the plant floor daily to provide assistance and improve OEE.					

SECTION C: AVAILABILITY

Please indicate the extent to which you agree or disagree with the following statements by marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	The machine availability of my area is visible and understood by everyone.					
2	Machinery stops often for maintenance problems.					
3	Every breakdown is captured and trended.					
4	All tooling losses are captured and trended.					
5	Does the machine often stop for idling and minor stops?					
6	All the setup and adjustments are recorded and trended.					
7	The company does have a changeover procedure.					
8	There are processes in place to reduce the changeover time.					
9	There are processes in place to analyse breakdowns and the root causes are identified and permanently fixed.					

SECTION D: PERFORMANCE EFFICIENCY

Please indicate the extent to which you agree or disagree with the following statements by marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	The performance efficiency of my area is visible and understood by everyone.					
2	Does the machine often stop for idling and minor stops?					
3	Does the machine often stop for dirty sensors?					
4	Certain machinery has longer cycle time than the design cycle time.					
5	When calculating efficiency the time allocated does not add up to 100% (there are always unidentified losses).					
6	There are regular cycle time studies being conducted on the machinery to ensure they still operate at their designed cycle time.					

SECTION E: QUALITY RATE

Please indicate the extent to which you agree or disagree with the following statements by marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	The quality rate of my area is visible and understood by everyone.					
2	The company does record the machine scrap, rejects and assembly return.					
3	The company does record the startup rejects.					
4	The company utilises Poka yoke to prevent errors.					
5	The company has measures in place to protect the customer.					
6	The company strives to continuously improve its products and processes.					

SECTION F: TOTAL PRODUCTIVE MAINTENANCE

Please indicate the extent to which you agree or disagree with the following statements marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	Maintenance artisans provide support to operators by having direct contact with the operator.					
2	Maintenance artisan's do preventive maintenance checks.					
3	Chronic problems with equipment are identified and eliminated.					
4	Condition monitoring has improved the reliability of the machinery in production areas.					
5	Maintenance Operating System has been communicated to plant employees.					
6	Detailed roles and responsibilities, and levels of authority for all maintenance personnel are well-defined, communicated, updated and understood plant-wide.					
7	Equipment is made available for maintenance, when scheduled, plant-wide.					
8	Appropriate Data Collection and Analysis (e.g. OEE, uptime) is used by the facility to eliminate equipment related losses					
9	Operators conduct daily checks on machinery and equipment they operate.					
10	People are encouraged to make and implement suggestions.					

SECTION G: TRAINING AND UNDERSTANDING

Please indicate the extent to which you agree or disagree with the following statements marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	People receive the training they need to do their jobs.					
2	People are coached and trained by their leaders/Supervisors.					
3	Are people encouraged to improve their knowledge and skills at work?					

4	Safety, ergonomic and environmental training programs has been provided for work group members and personnel involved in the maintenance process					
5	The facility provides the appropriate training to support the maintenance process					
6	I have received the Basic Equipment Wellness training One (BEW1) which involves 7 steps of BEW.					
7	I have received Ford Production Systems (FPS) over view training					
8	I have received Ford Total Productive Maintenance (FTPM) over view training					
9	I have received a Value Stream Map (VSM) training					
10	I have received training on 5S.					

SECTION H: HUMAN FACTORS

Please indicate the extent to which you agree or disagree with the following statements by marking with an X on the appropriate box.

	STATEMENT	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1	Ford management care for or look after their employees well being.					
2	The space provided for workers is large enough for them to perform the required task.					
3	The machines are designed to provide failure indications to make troubleshooting fast, simple, and easy.					
4	At Ford before you put any part of your body in danger inside or near a machine, you must first isolate and lockout the energies.					
5	Operators do basic maintenance and inspect their machines as well as operate them.					
6	Ford encourages team work					
7	Is there an opportunity for people to acquire and enhance skills and experience and develop their full potential?					

SECTION I: RESPONDENTS OPINION

Please write down you own opinion with regards to these sections indicated below. Please print when you write, keep it sort and be clear.

SECTION C: AVAILABILITY

How can the company improve machine availability?

_____

_____

_____

SECTION D: PERFORMANCE EFFICIENCY

How can the company improve performance efficiency?

_____

_____

_____

SECTION E: QUALITY RATE

How can the company improve its quality?

_____

_____

_____

SECTION F: TOTAL PRODUCTIVE MAINTENANCE

How can the company improve its total productive maintenance?

_____

_____

_____

SECTION G: TRAINING AND UNDERSTANDING

What do you think about the training you have received in the company?

_____

_____

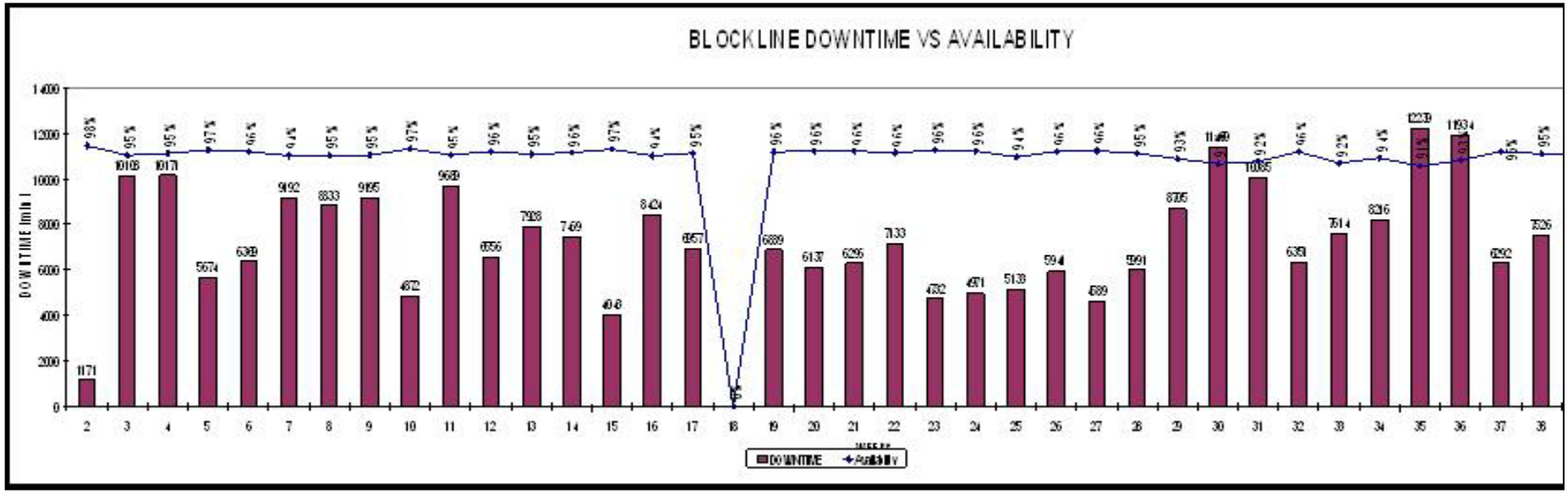
How can the company improve the training?

_____

_____

_____

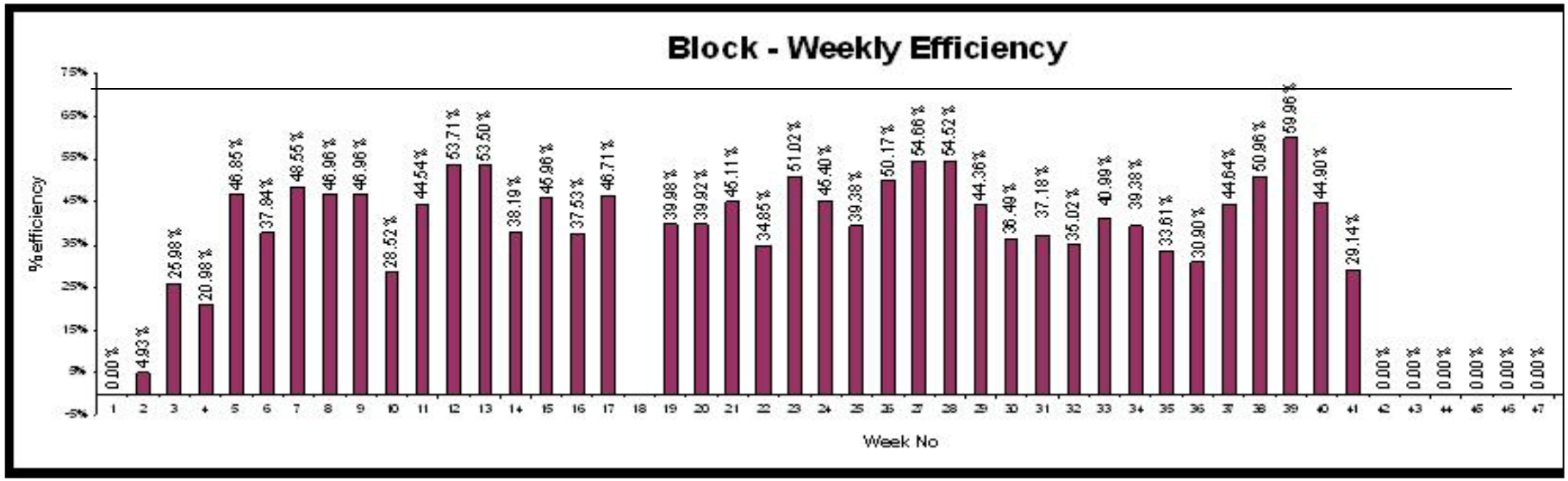
DOWNTIME VS AVAILABILITY

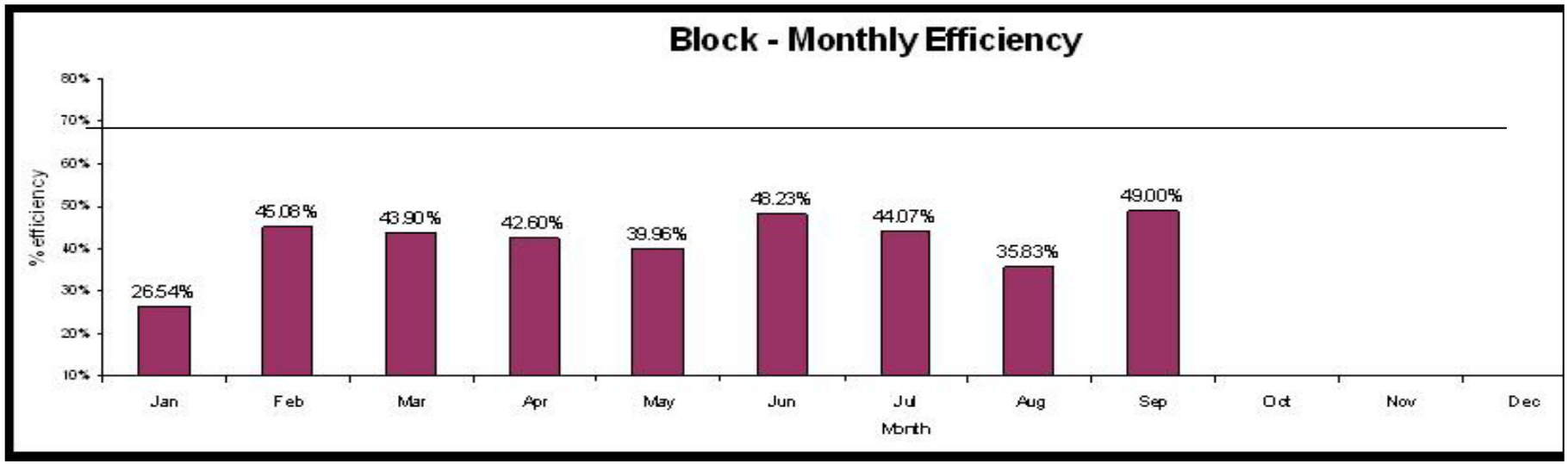


		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Grand Total
1	Tooling change unscheduled (Broken, Jammed, etc.)	15	439	452	827	493	1011	845	1044	855	536	988	939	429	578	646	492		955	625	719	1104	790	1136	297	1039	562	964	360	473	1563	278	298	965	763	425	1605	1200	629	2823	28553
2	Clamping fault		543	276	730	260	506	247	1377	985	398	260	253	859	65	2948	427		210	279	730	745	1893	766	404	382	730	367	380	260	218	675	225	278	1115	937	385	25		137	18454
3	Quality issue		90			85		500	158	262	429	15	620	155	165		476		1313	65	380	995	295		316	470	58	974	180	2025	287	682	676	1147	952	1363	777	1655	470	1890	18970
4	Setting	45	204	957	406	485	560	500	720	210	370	1067	1139	195	268	413	326		255	130	685	515	180	290	306	272	117	98	300	125	168	60	378	1269	248	20	365	240	200	125	14156
5	Transfer fault	20	526	1060	90	480	925	574	627	98	573	249	291	1027	452	358	316		177		45	45	235	298	60	480		28	115	15		448	246	245	428	444	200	170	647	165	12129
6	Gantry fault		90	487	245	342		229	383	65	111	339	147	246		95			28	165	35	18	420	117	10		18	17	722	198	43	96	472	61		1876	95	1699	10	420	9139
7	Coolant fault/level/overflow	85	155	260	256	331	195	130	25	65	99	45	38	308	25	115	93		625	634	195	145	175	15	160	280	130	367	95	35	168	325	208	122	95	375	210	55	1526	145	8133
8	Tooling change schedule		175	50	380	145	399	290	186	380	241	389	172	160	195	173	498		175	75	370	375	35	210	160	160	115	180	185	65	95	139	168	252	194	393	130	185	365	245	7777
9	Roll over fault	55	642		10		160	136	70	377	580	289	173	749	50	359	581		25	265	1156	600	135	15	28	68	15	35	83	85	22	60	45			15	10	35	204	69	7161
10	Swarf conveyer fault											48	25		57				75									185	980	2255	1800		608		870					150	6967
11	Blocks filled the basket		285	175	230	305	665	65	15	28	78	569	109	30	50	278	115		323	315	286			65	70	68	180	430	83	410	250	85	25	35		80	20	86		55	5964

Source: W:\GROUP\FPS\2. FPS Department\09. Department Information\Production\2009\1. Downtime

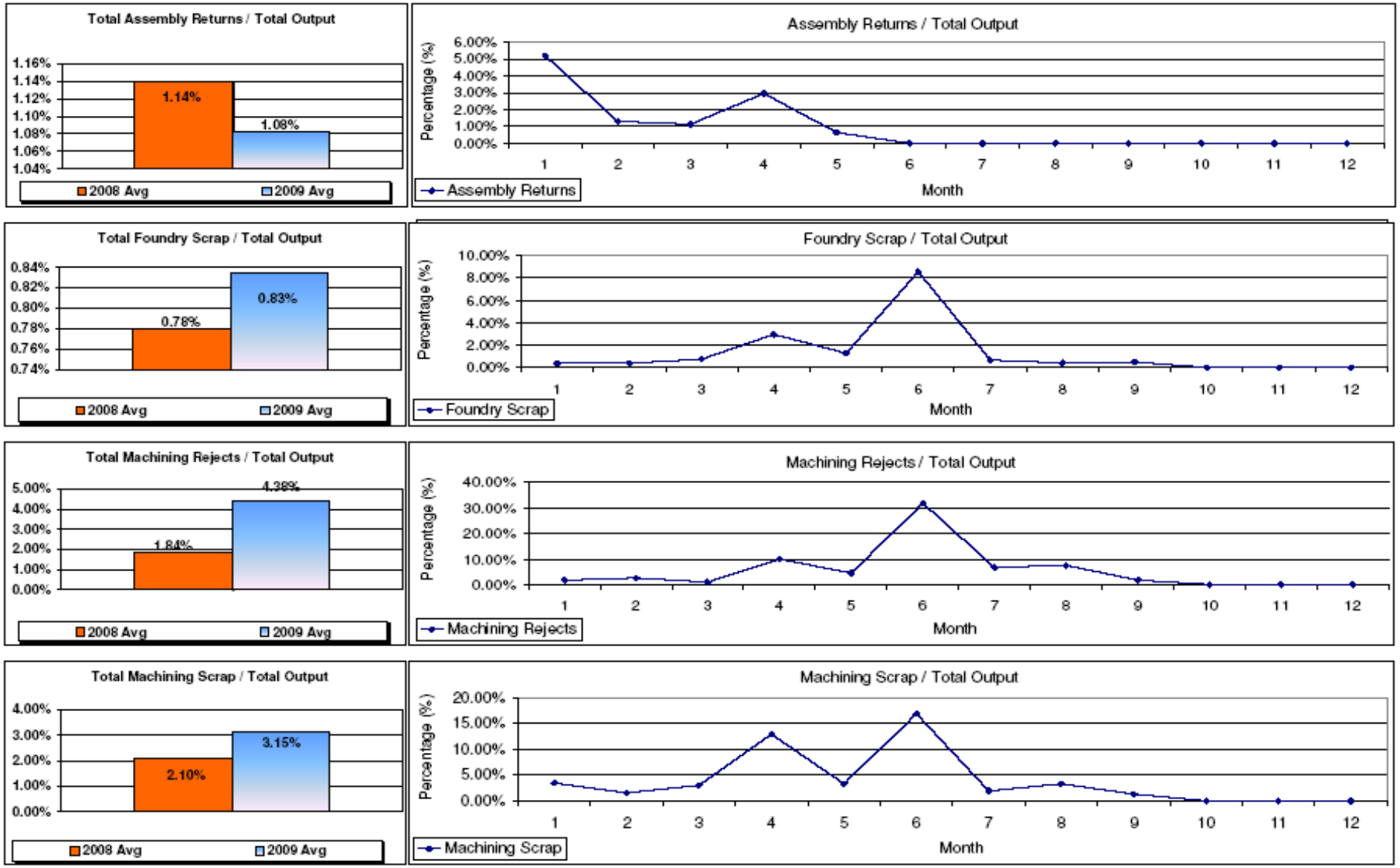
PERFORMANCE EFFICIENCY





Source: W:\GROUP\FPS\2. FPS Department\09. Department Information\Production\2009\2. Efficiency

QUALITY RATE



Source: W:\GROUP\QC\Quality Reports\Reports 2009