Tools for the revision of a maintenance strategy for an explosives manufacturing plant, using Asset Management principles

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I. CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled "Tools for the revision of a maintenance strategy for an explosives manufacturing plant, using asset management principles" in partial fulfilment of the requirements for the award for the degree M. (Eng) in Development and Management at the NORTH WEST UNIVERSITY is an authentic record of my own work carried out during the period from January 2006 to August 2009, under the supervision of Prof. J.H. Wichers. This dissertation has not been submitted by me to any other University / Institute for the award of the degree M (Eng) in Development and Management.

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II. ACKNOWLEDGEMENTS

To my heavenly Father who gave me the privilege to do research and to use and develop the wonderful gift of human intelligence and His love for His creations.

I would also like to express my gratitude to the following persons and organizations for their contributions towards the success of this dissertation:

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- SASOL NITRO explosives division for the opportunity to conduct interviews at the Sasolburg operation.
- My promoter, Prof. J.H. Wichers for his guidance, advice and support during my studies.

III. ABSTRACT

The research topic is: Tools for the revision of a maintenance strategy for an explosives manufacturing plant, using asset management principles. This research has specific reference to the SASOL Prillan plant based in SASOL, Sasolburg. The purpose of this research is to identify tools for the revision of a maintenance strategy for an explosives manufacturing plant, using asset management principles. These tools must be aimed to increase the proactive work capacity index, Figure 3, and to identify and/or develop tools that can be used by the engineering team of this explosives manufacturing plant to increase equipment reliability and performance. In this research assets include people. The meaning and application of asset management principles were researched and the tools needed to combine existing efforts and future needs are discussed. The human element to ensure the successful implementation of an asset management culture was researched and attributes of leaders and a change model is presented. This research was done into the wider engineering management discipline and not only maintenance.

The method used to gather data was by means of interviews of a sample group within this organization. As this manufacturing unit makes use of subject matter experts, these support functions and plant personnel that were not interviewed, were issued with questionnaires to ensure that the sample group is a fair representation of the total manufacturing facility. To obtain a holistic view of potential shortcomings within the current maintenance strategy, all disciplines and levels within this operation were interviewed and commonalities of various asset management models were determined and used to define existing problem areas. This data was used to determine statistical correlations. The case study presented in Chapter 1 indicates that there is a case for change that can improve the proactive work capacity index of the engineering team. The results of this research confirm that there is in fact a real requirement to increase spares accuracy, improve on technical training as well as a need to establish visual performance indicators (dashboard) to measure overall equipment efficiency with the goal to

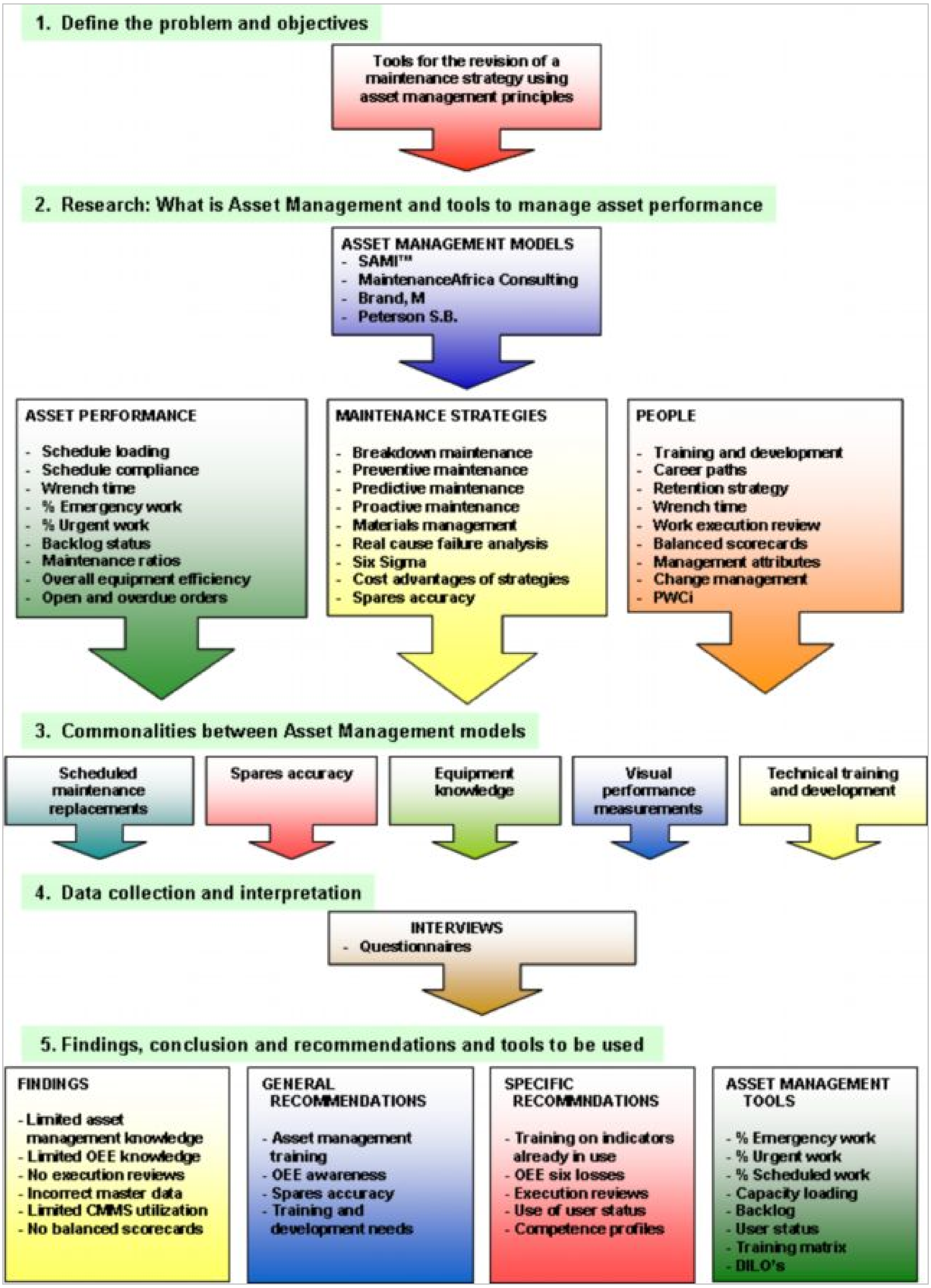
increase equipment reliability and performance. The technical training referred to in this research reflects on training of people on equipment after investment in new technology. The current spares holding strategy is lacking equipment description accuracy.

Furthermore, it is recommended that the implementation of career paths and development plans for individuals must be developed to create an environment of learning. The use of user status information captured on the computerized maintenance management system (SAP R/3) can add to the management of works orders and indicate where the focus must be to complete overdue work orders. Open work orders should be used to manage expenditure, to measure planning efficiency and to manage the cash flow of the business. The use of overall equipment efficiency and engineering efficiency measures is recommended and must be visually displayed on a “dashboard”. It was recommended that the engineering and operations personnel of this manufacturing plant be trained in asset management principles and that balanced scorecards are developed to ensure that the strategies of the various departments are aligned with the business strategy.

Diagram 1 best illustrates the thinking and process flow of this research. The flow diagram shows five distinct stages and the appropriate objectives and/ or elements that were considered. The dissertation is also structured in this manner.

All abbreviations, acronyms and definitions used in this document were listed in APPENDIX B

DIAGRAM 1 – Dissertation Thinking Process Flow Diagram



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CHAPTER 1 - PROBLEM STATEMENT AND INTRODUCTION

1.1 Purpose and Chapter Outline

The purpose of this chapter is to define the problem and the required outcome of this study. It has specific reference to the need of a "dashboard" to measure and evaluate plant and engineering activities effectiveness. The result of this research must be to enable the engineering team to increase the proactive work capacity index of this plant and to provide tools to achieve this outcome. The overall and specific objectives of this research are defined in this chapter. This research will identify either existing tools or tools that can be developed that can be used to revise the existing maintenance strategy and measure the overall equipment efficiency. This chapter describes the manufacturing process and plant history and summarize the thinking process of the researcher. A case study on asset healthcare is included (SAMI Inc, 2005, *Prillan Explosives Plant Asset Healthcare Case Study*).

1.2 Manufacturing Process and Plant History

The P.P.A.N. (Porous Prilled Ammonium Nitrate) plant in Sasolburg produces 800 metric tons per day, low-density ammonium nitrate, known as explosive-grade. It is mainly used in the manufacturing process of various types of explosives. This grade differs from high-density ammonium nitrate, used as fertilizer, mainly because of higher porosity characteristics.

The manufacturing capacity of the existing manufacturing plant situated in Sasolburg, was increased during its lifetime from 220t/day to 800t/day to maintain profitability and to successfully compete against international and local manufacturers (R. Wigget, 10 October 2003, *Board meeting*).

The 90% ammonium nitrate solution supplied to the PPAN plant from a liquid storage facility together with off-size product and ammonium nitrate solution from the scrubbing system are mixed in ammonium nitrate feeding and dissolving tanks by using an agitator. The tank is equipped with a steam coil to provide dissolution heat to enhance the mixing process. From the ammonium nitrate feeding and dissolving tanks the ammonium nitrate solution is pumped to two evaporators where the solution is concentrated to 97% ammonium nitrate content.

The evaporators are of vertical one pass design, and are operated at a pressure of 0.40 Bar and a temperature of maximum 160°C. The temperature is controlled by adjusting the steam supply volume to the evaporators. The vapours from the evaporator are condensed in a condenser and the condensate is re-used in a scrubbing system to control emissions. Vacuum to transfer the vapours is obtained by means of a steam ejector.

The concentrated ammonium nitrate solution is pumped to a prill feed surge tank, in which some gaseous ammonia is added to control the pH at a value of 6, 0. This is a manual process and will in future be automated.

From the prill feed surge tank the ammonium nitrate solution is pumped to the head tank, which is located at the top of the prilling tower. This is only done if the PH value is within defined limits. The ammonium nitrate solution is gravity fed through 8 nozzles, which is equipped with showerhead plates. The showerhead plates forms liquid droplets of ammonium nitrate. When these droplets fall down the 40 meter high tower, the droplets solidify.

The heat from the solidification process is removed with air flowing in the opposite direction as the droplets by using electric driven fans installed at the top of the prilling tower. The air from the tower is scrubbed and the water is fed to the top scrubber tank, which in turn overflows to the bottom scrubber system for re-use in the process.

The bottom of the tower is shaped in a conical form, which allows air inflow through openings in the structure. Prills are transferred by means of a conveyor that is situated in the centre of the conical section.

These ammonium nitrate prills are first dried in a pre-dryer with co-current hot air flow induced into the drier. From the pre-dryer the prills are led into a dryer where they are further dried using the same technology. The product leaving the dryer is fed to a rotary cooler, using a bucket elevator. Cool air is induced using an industrial air conditioning system.

The air leaving the pre-dryer, dryer, cooler and de-dusting system is also treated in scrubbers where ammonium nitrate dust is removed.

The cooled product is led onto screened vibrators, where the prills are separated into oversize, undersize and on-size product. The oversize and undersize product is returned to the ammonium nitrate feed and dissolving tanks.

The on-size product from the screen is led into a fluidized bed plate cooler where the product is further cooled to ± 31°C. The product then enters a coating unit where the product is coated with an oil/wax/ATH mixture in order to decrease the caking tendency. After coating, the product is finally transported via a reversible weigh-belt to a storage facility (Gent C, 2005, *Prillan plant induction manual)*.

1.3 Products of the Plant

The following are products manufactured by the plant (http://www.sasol.com, Accessed 9 November 2006):

- Expan 400 with a density of 0,750 to 0,770 ton/m^3
- Expan 300 with a density of 0,690 to 0,750 ton/m^3
- Expan 200 with a density of 0,650 to 0,690 ton/m^3
- Expan 100 with a density of 0,590 to 0,650 ton/m^3

PHOTO 1 – AMMONIUM NITRATE

http://www.alibaba.com, Accessed January 19, 2007

1.4 Problem Statement

The Prillan explosives manufacturing plant asset healthcare case study, Chapter 2, indicates that there are limited tools identified, and in use, that can be utilized by the plant management to increase the equipment reliability and asset performance.

The proactive work capacity index, Figure 2, indicates that schedule compliance, schedule loading and wrench time must be increased to compare with world class standards.

1.5 Purpose of this Research

The purpose of this research is to identify tools for the revision of a maintenance strategy for an explosives manufacturing plant, using asset management principles. These tools must be aimed to increase the proactive work capacity index, Figure 2. The application of asset management models must be researched and the commonalities between these models must be established to provide a roadmap for implementation. Data must be collected and then be evaluated against these commonalities to prioritize actions required to increase plant integrity and equipment and engineering efficiency, using asset management principles. Leadership attributes and a change management model must be presented.

The proactive work capacity index (PWCi), Figure 2, must be increased. The PWCi is a factor determined by the product of the wrench time, schedule loading and schedule compliance. Influences on wrench time (spanner time) are:

- Material availability
- Travel time
- Instruction time
- Administration time
- Tool preparation time
- Meeting time
- Waiting time
- Break time

To understand the recommendations of this research, the reader will be presented with a basic understanding of:

- The manufacturing process and workflow of the Prillan explosives manufacturing plant based in Sasolburg
- The plant history to identify with the current low pro-active work capacity index
- The principles and application of asset management models applied within similar industries
- Different maintenance strategies and the application thereof in manufacturing plants
- Overall equipment efficiency (OEE) and how this is measured
- Different maintenance ratios and benchmarks on these ratios
- Basic materials management principles and philosophies
- Measurements of engineering team effectiveness
- Management processes and leader attributes needed

1.6 Specific Deliverables

Asset management tools must be developed that can be applied to revise and manage the maintenance strategy of an explosives manufacturing plant. These tools must have the ability to be visually presented as a "dashboard" to trend and manage asset performance and reliability and to increase the proactive work capacity index of the engineering team.

These tools must include:

- Tools to measure and evaluate engineering execution performance
- Tools to measure the overall equipment efficiency
- Tools to manage overdue open works orders
- Tools to align departmental and business mission and strategy
- Tools to optimise and measure engineering planning effectiveness

"It is good practice to revisit current strategies regularly and evaluate their effectiveness. One must change one's tactics every ten years if one wishes to maintain one's superiority"– *Bonaparte Napoleon* (http://www.famousquotesandauthors.com, Accessed 12 January, 2008)

The outcome of this research is aimed at positioning the existing technical department to effectively maintain the explosives manufacturing business, and to contribute to a sustainable Sasol owned business by applying asset management tools. A picture of the strategy must be formulated in the minds of the maintenance personnel, not only words that can be interpreted differently. For this reason a visual "dashboard" that can be interpreted by all engineering personnel must be designed. The SAMI triangle model can be used as a required end state picture if training and coaching in the interpretation of all the building blocks are provided. The people affected by the implementation of the recommendations from this research must be change ready to make the implementation of a revised strategy lasting, and to ensure that there are limited and manageable barriers and resistance to change.

1.7 Chapter Summary

The manufacturing process flow and plant history is described in this chapter. The fact that the proactive work capacity index is at 0.11 versus a world class standard of 0.53, Figure 2 , indicates that the current maintenance strategy and the utilization and application of the available engineering resources can be improved (Hedding R, SAMI™, 2005). This chapter states the required deliverables namely tools that can be used to revise and manage the revision of the current maintenance strategy by using asset management principles. These tools must have the goal to improve on asset reliability and performance and to increase the proactive work capacity index and must include:

- Tools to measure and evaluate engineering execution performance
- Tools to measure the overall production effectiveness
- Tools to manage overdue open works orders
- Tools to align departmental and business mission and strategy
- Tools to optimise and measure engineering planning effectiveness

These tools must have the functionality to be trended over time to manage assets.

Chapter 2 aims to provide the reader with literature review to define existing asset management models and measurements that can be used to ensure the sustainability of the implementation of an asset management model. The influence of employees on this strategy must be reviewed and a change management model must be used to ensure the successful implementation of an asset management model.

CHAPTER 2 - LITERATURE REVIEW

2.1 Purpose and Chapter Outline

The purpose of this chapter is to do literature review on asset management models and to determine the common elements of these models. This is the catalyst to make recommendations to close gaps within the current maintenance strategy and to identify tools that can be used to increase the proactive capacity work index, Figure 2 – RESULTS OF 2005 PROACTIVE WORK CAPACITY INDEX COMPARISON TO WORLD CLASS. Various maintenance strategies, their applications and benchmarked ratios for maintenance measurements are presented. From this literature review tools can be developed that can be used to revise the current maintenance strategy and to establish an asset management culture.

When a manufacturing facility is continuously upgraded and modified, audits need to be conducted to ensure plant integrity. The results of these audits revealed that there were shortfalls with regards to plant integrity (AIA, May 2006, *Mechanical integrity audit*), legal compliance (Smit F, 2006, *Legal compliance audit*) and equipment reliability (Turbo Services, 2006, *MTBF report on pump performance*). A spares audit conducted indicate that the spares kept do not correspond to the actual plant needs and that the spares description on the plant master data do not reflect the technical specification required (Oosthuyzen P, 2006, *Inventory audit*).

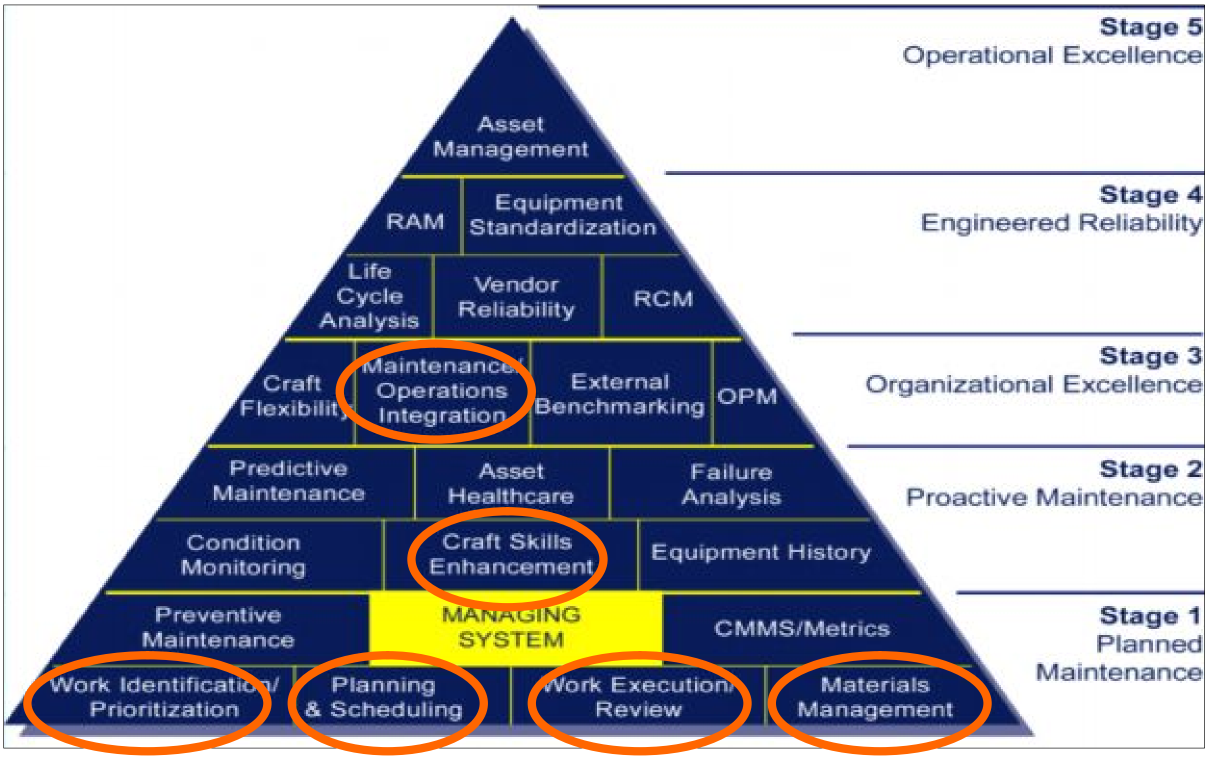
This chapter will take into account the human element that is necessary for the revision of the maintenance strategy. The human element includes change management and the attributes and involvement needed from the management of that plant. A management tool to ensure that the various departmental strategies and that of the overall business are aligned will be presented.

2.2 Prillan Explosives Plant Asset Healthcare Case Study, SAMI Inc, 2005.

2.2.1 Background

Sasol Limited assigned SAMI inc. as management consultants to establish an asset management model within most of the Sasolburg operations, of which the explosives division forms part. This dissertation will be aimed at supporting the SAMI™ asset management model, Figure 1, and give recommendations on how to entrench this asset management culture.

FIGURE 1 - SAMI Asset Healthcare Triangle



SAMI™, 2004, Asset healthcare triangle

The red circled areas in Figure 1 above indicate where human intervention is of utmost importance, and therefore change in behavior is essential.

2.2.2 Objectives

Maintenance performance indicators for selected Sasolburg based production facilities were compiled and compared to world class standards in 2005. Some of these indicators are existing indicators in use and must be evaluated for its effectiveness. These results were obtained from using existing data on the SAP R/3 system and by using techniques such as DILO's (Day-In-the-Life-Of). These indicators are referred to as engineering team effectiveness measurements. Figure 2 indicates the gap between the current and projected proactive work capacity index. The proactive work capacity index is the product of schedule compliance, schedule loading and wrench time. This is a leading measure to provide for time to correct any deviations from a set target. A higher value of this index can be interpreted that planned preventative maintenance is done as planned and that available manpower is optimally utilized.

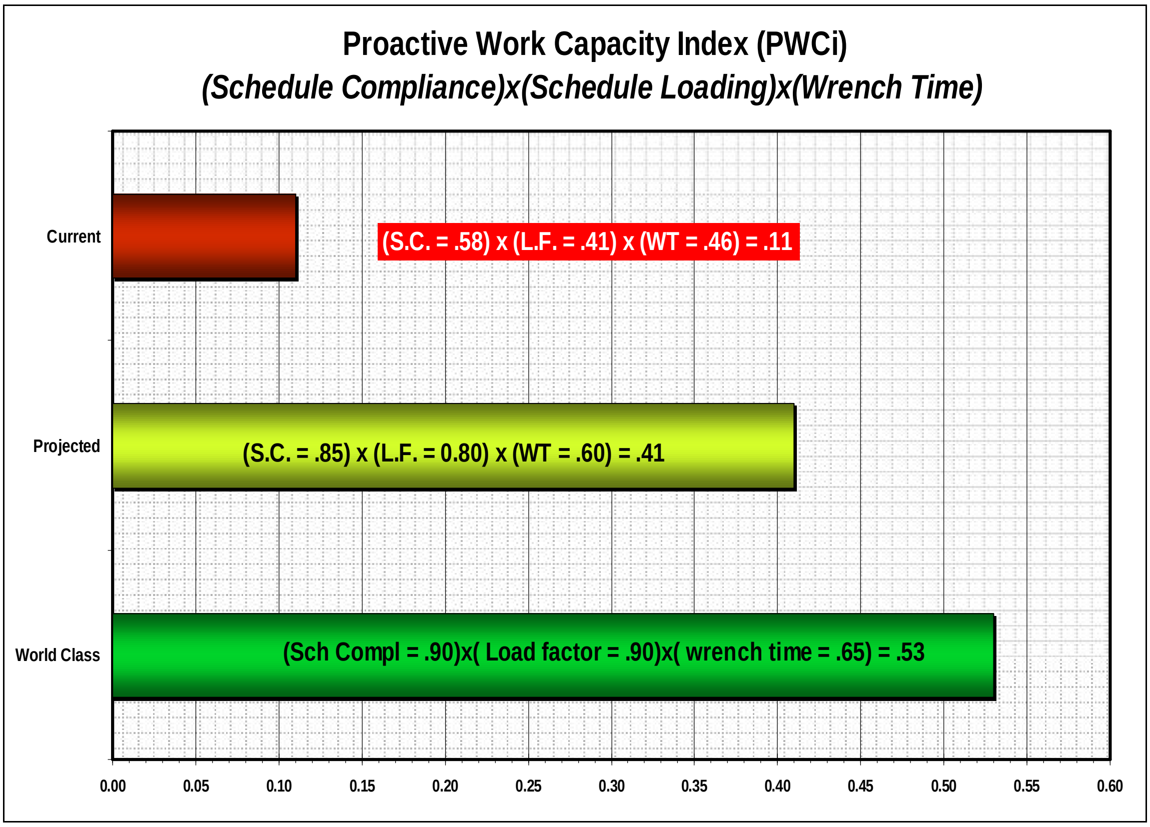
Schedule compliance is the measure to indicate if scheduled work were complied too. As most of the preventative maintenance scheduled work in an explosives plant environment has statutory requirements, the ideal compliance must be 100%. A high compliance factor indicates that planned work was actually done.

Schedule loading measures the available man-hours that are scheduled. This target is set at 90% to allow for emergencies and any other unplanned work. A higher value of this load factor indicates that emergency and breakdown activities are under control.

Wrench time is defined as the physical metal to metal work (http://samicorp.com, Accessed February 21, 2006). Results of different wrench time calculations will vary between individuals within the same department but gives a good idea on where opportunities are to increase the engineering team effectiveness.

2.2.3 Results

FIGURE 2 – Results of 2005 proactive work capacity index comparison to world class

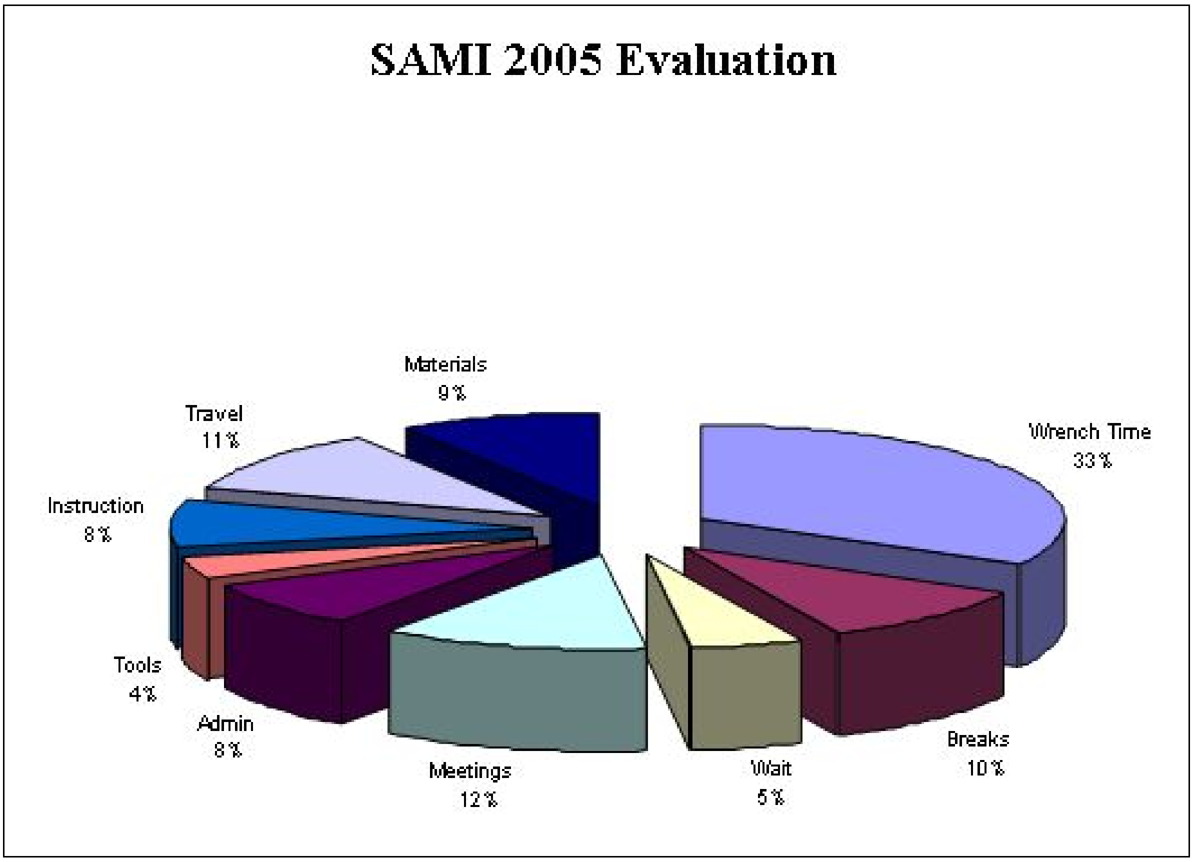


SAMI™, 2005, Prillan proactive work capacity index comparison to world class

The proactive work capacity index includes wrench time and to understand the activities performed by the engineering team a DILO (Day in the life of) was performed on selected personnel.

A DILO was performed on a mechanical artisan in 2005 and yielded the following results:

FIGURE 3 - DILO on mechanical artisan, Explosives manufacturing plant, 2005



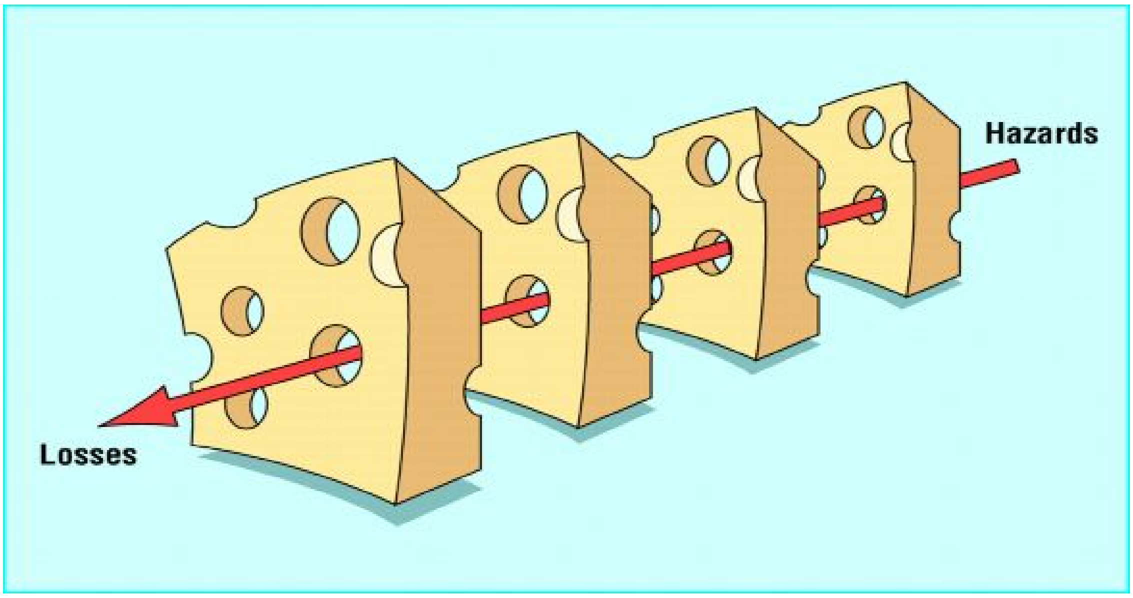
SAMI™, 2005, DILO analysis of mechanical artisan

2.2.4 Conclusion

Gaps identified from this case study are:

- The schedule compliance is lower than world class, can be improved
- The load factor is lower than world class, can be improved
- Wrench time is lower than world class, can be improved

FIGURE 4 - Swiss cheese model



http://www.pubmedcontrol.nih.gov, Accessed 15 August, 2008

Reason J. T. (1990) defines the holes in as weaknesses in various processes that must be aligned to achieve a specific outcome. If this theory is correct then the inverse must also be correct. These holes can also be projected as required fundamentals that must be in place and aligned to achieve a specific outcome, such as the implementation of a revised maintenance strategy.

When a strategy is developed and implemented it must be to the advantage of all the parties affected. The shareholders with regards to return on investment and market share, the customers with regards to product quality, price and service, and for the employees by creating work security, financial gain, growth and development opportunities.

2.3 Asset Management

Mitchell J. S. (2002:9) states that asset management provides the basis for collectively optimizing investment, resource allocation, and spending decisions to gain greatest lifetime return. Its emphasis is on achieving maximum sustainable lifetime effectiveness from design, procurement, and installation through operation, maintenance, and eventual replacement or de-commissioning.

The maintenance cost of the explosives manufacturing plant was on average 25% of the total fixed cost measured over a period of 5 years, 2001 to 2005, Smit A, 2005, Sasol Nitro financial department. This fixed cost includes:

- Labour cost
- Maintenance cost
- Information management and software cost
- Administration cost
- Management allocated cost (10% of total fixed cost)
- Depreciation expense

Savings on the fixed cost budget as a result of an effective maintenance strategy and effective resource utilization can be very significant. In this research the Reliability Centred Maintenance (RCM) approach is discussed as a tool to develop equipment maintenance strategies that can result in higher plant availability and lower input fixed cost. This approach indicates what maintenance strategy for a piece of equipment is applicable by identifying the impact of failures. It is sometimes the correct approach to run equipment or part thereof to failure (Mitchell J. S, 2002). There must however be a continuous drive to eliminate maintenance activities where possible. World class practice for reactive maintenance is 20% of all maintenance activities (http://www.emmersonprocessxperts.com, Accessed 19 May 2008). Reactive maintenance is later referred to as priority 1 (emergency) and 2 (urgent) work.

2.4 Asset Management Models

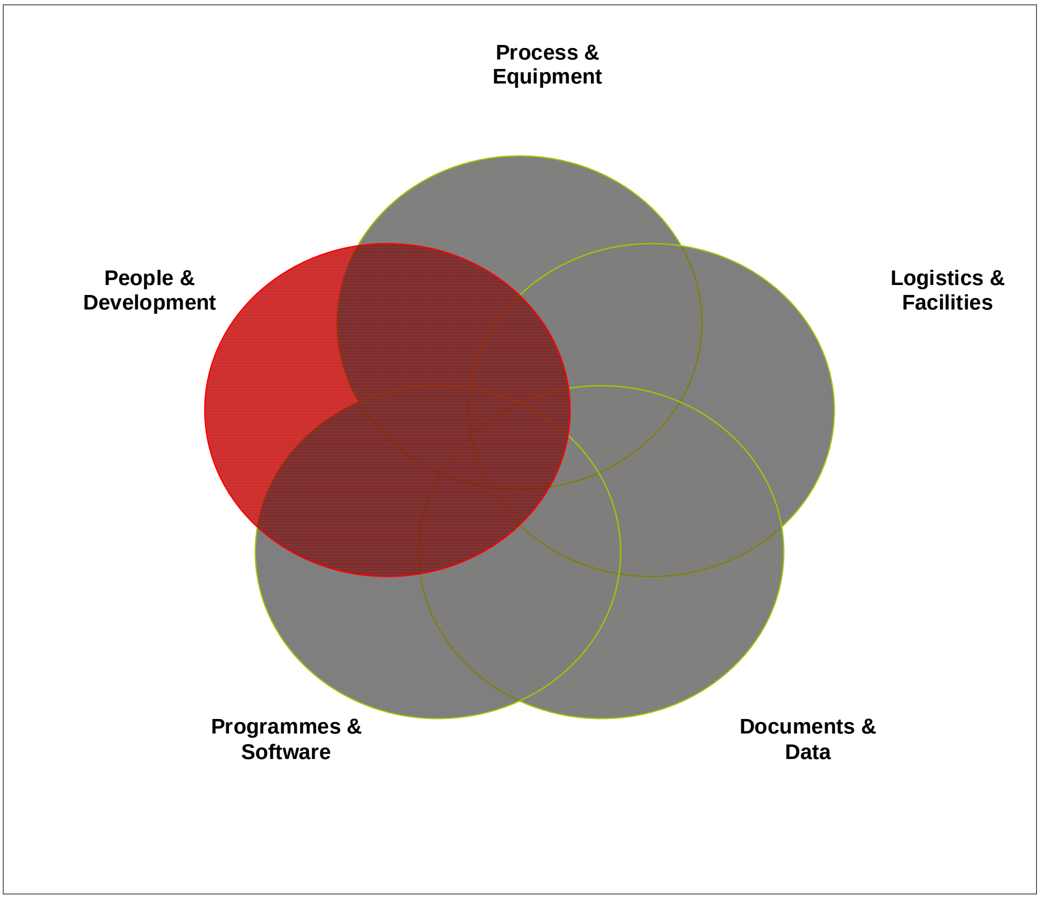
Asset management is a comprehensive, fully integrated, strategy, process, and culture directed at gaining greatest lifetime effectiveness, value, profitability, and return from production and manufacturing assets (Mitchell J.S, 2002:3).

Physical asset management is an integral, inseparable part of the production and manufacturing processes. Design, procurement, installation, operation and maintainability to ensure that in-service reliability matches business and mission requirements are all included in physical asset management (Mitchell J.S, 2002:3).

By using asset management principles in the development and implementation of a maintenance strategy, the plant integrity, safety and reliability will be increased. An asset management approach will include the people development and training component of the asset management components, Figure 5.

Figure 5 illustrates the asset management components. This illustration can be summarised as people, process and technology.

FIGURE 5 – Asset Management Components



Pretorius H, 2007, Maintenance Africa, Asset management components

An asset management strategy must include the following elements (Peterson S.B, 2004, Defining Asset Management):

- Empowered Workforce
- Reliability Centred Maintenance
- Work Management Processes
- Predictive and Preventive Maintenance
- Self-managed Work Teams
- Measures of Leading and Lagging KPI's
- Reliability Leadership and Planning
- Safety, Health and Environment
- Continuous Improvement
- Reliability Modelling and Equipment Risk
- Assessment
- Cost of Unreliability Tracking
- Root Cause Failure Analysis
- Capacity/Business Objectives Modelling
- Lifecycle Costing/Engineering
- Activity-based Management

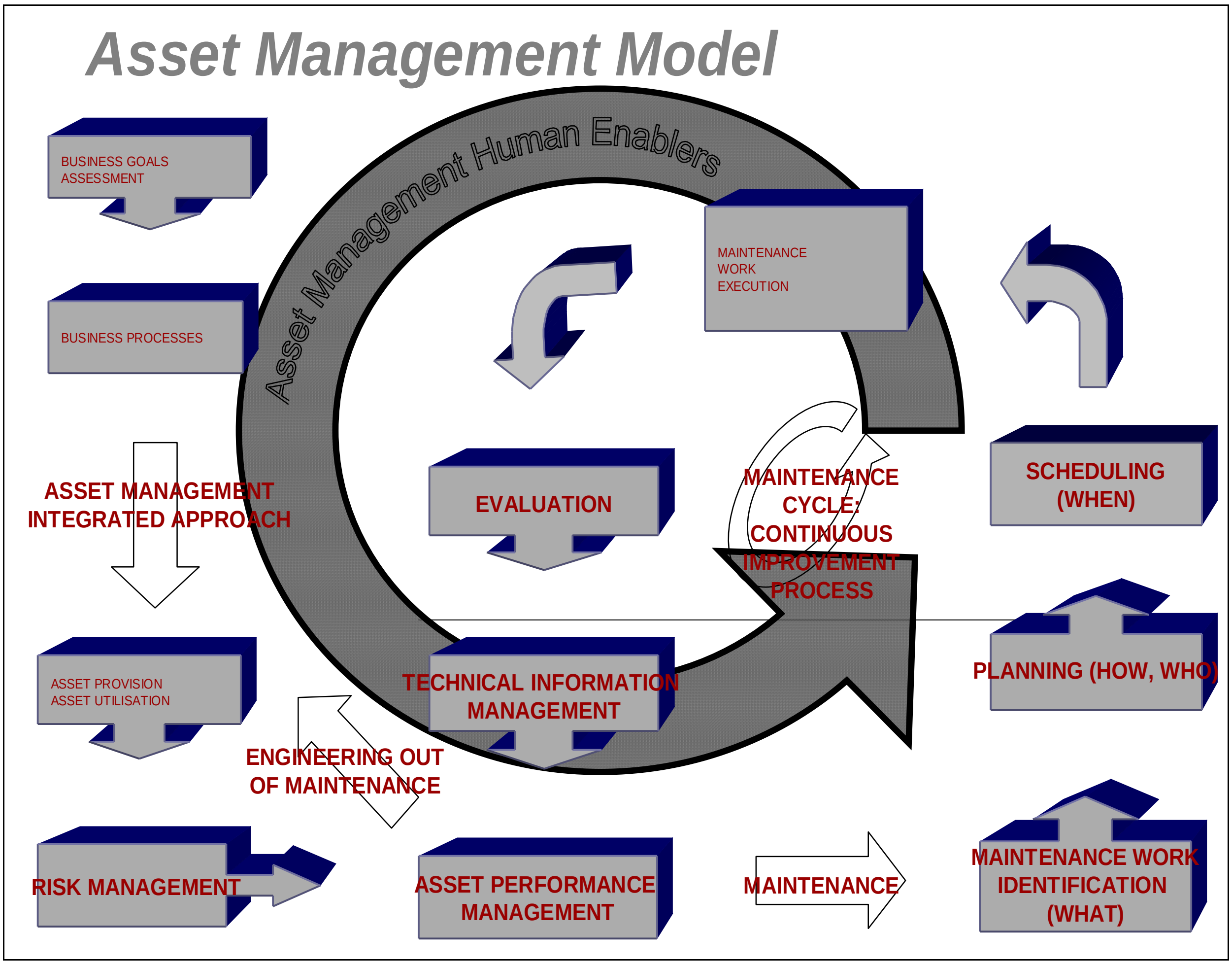
This research will have specific reference to "quick wins" to increase the proactive work capacity index of the engineering team. Army D, 2006, The SAMI Times, Volume 7, states that change management is an integral part of asset healthcare. Coaching through the change process is important to make the change a lasting experience.

The skills needed to run today's factories and buildings are changing faster than people can adjust, Levitt J, (2005:241). This illustrates the importance to invest in a people development and retention strategy.

There are many asset management models available on which a maintenance strategy can be developed and revised. The model used by Brand M, 2004, Figure 6, defines these strategy elements as “Asset Management Human Enablers”.

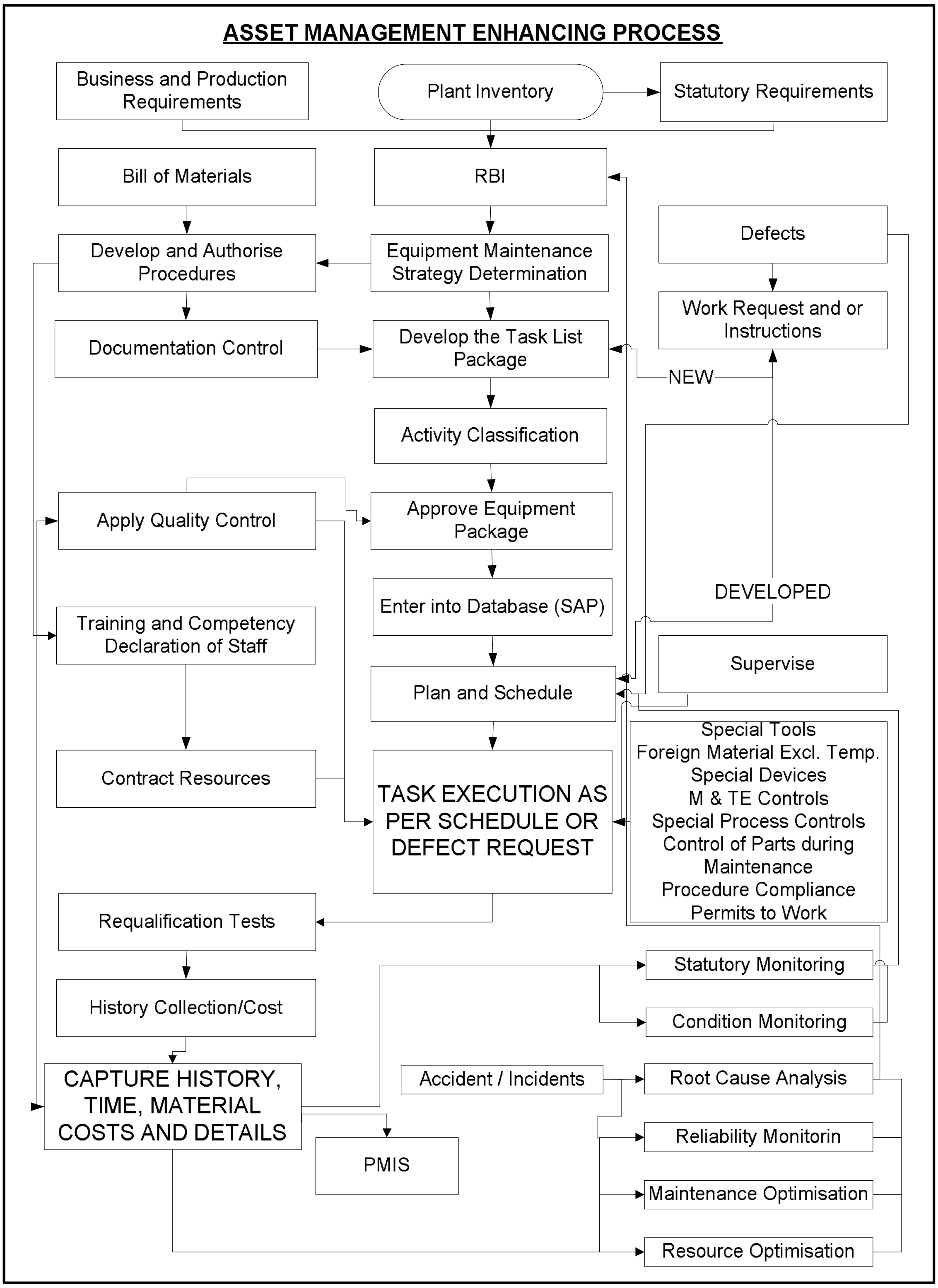
The catalyst of all the asset management elements is the human enablers to ensure that this is a continuous improvement process and that it is sustainable (Brand M, 2004, Sasol Synfuels). The total business and all the role players must accept that change will happen and they must be “change – ready”. The success of any new strategy will depend on the preparedness and willingness of the employees to improve on their current achievements, and to understand that what was good enough yesterday is not necessary good enough today and for the future (http://www.cultureandrecreation.gov. au, Accessed 20 January, 2009). Employee willingness and preparedness can be achieved by making all the people affected by this change, part of the design of the “to-be” strategy. The development and revision of the current maintenance strategy must have a project management approach to ensure that the deliverables are met within the planned cost and schedule.

FIGURE 6 - Process flow of the asset management model



Brand M, 2004, Sasol Synfuels

Figure 7 - ASSET MANAGEMENT ENHANCING PROCESS



Brand M, 2004, Sasol Synfuels

2.5 Maintenance Strategies

Mitchell J.S, (2002) states that asset management is a combination of concepts and approaches from various maintenance strategies. These include reactive, preventive, condition based (predictive), proactive, reliability centred approaches and total productive maintenance strategies.

2.5.1 Breakdown (Reactive) maintenance

This strategy is purely reactive and requires no scheduled or planned maintenance tasks. The correct application of this maintenance strategy normally results in the repair or replacement of components and the failure does not impact on the process. When not applied correctly or controlled this can result in large and uncontrollable maintenance expenditure (Levitt J, 2005). The total cost of failures, including safety and environmental, impact on production, repairs and logistics, are typically spread among cost centres. When this strategy is applied the decision must be based on probability, cost and consequences.

2.5.2 Preventive Maintenance

This is a time based maintenance strategy where equipment is taken off-line to be inspected for fitness. This is a well established strategy in the chemical industry and scheduled “mayor-shutdowns” is the result of this strategy. This fits in well with legislation such as the Occupational Health and Safety Act that describes pressure vessel testing and inspection every 36 months. This period can be extended by applying Risk Based Inspection (RBI) studies on the equipment. This is a technique that takes statistical data and operating conditions and products handled into account to determine the frequency of inspection and testing of equipment. This study is performed by a panel of subject experts and includes process, maintenance, metallurgical and operating personnel. World class performance is at 35% of maintenance activities spend on preventive maintenance (http://www.emmersonprocessxperts.com, Accessed 19 may 2008). This strategy can be cost effective when equipment operation is consistent, average life is predictable, failures are well understood and useful failure statistics are available (Mitchell J.S, 2002).

2.5.3 Predictive (Condition based) Maintenance

This strategy is condition-based and data is used to predict failures. This data can be used to determine the condition of equipment and to evaluate when corrective action must be taken. This strategy makes use of technologies such as vibration, temperature and ultrasonic detectors, oil analysis and visual techniques. Measuring equipment can be permanently installed for continuous monitoring or can be hand held. Human senses form part of this strategy and inspections schedules can be designed to include frequent equipment inspections. World class companies spend 45% to 55% of their maintenance activities on predictive maintenance (http://www.emmersonprocessxperts.com, Accessed 19 may 2008).

Mitchell J. S (2002:61) states that condition based maintenance can:

- Warn of most mechanical problems in time
- Increase equipment life and utilization
- Reduce maintenance cost – both parts and labour
- Allow for reduction in preventative maintenance
- Minimize cost and hazard to equipment as a result of unnecessary overhauls
- Increase the likelihood that components operate to optimum lifetime
- Reduce requirement for spare parts
- Increase awareness of equipment condition
- Form the core of effective lifetime management
- Provide information for continuous improvement, work, and logistic planning

Condition based maintenance will not:

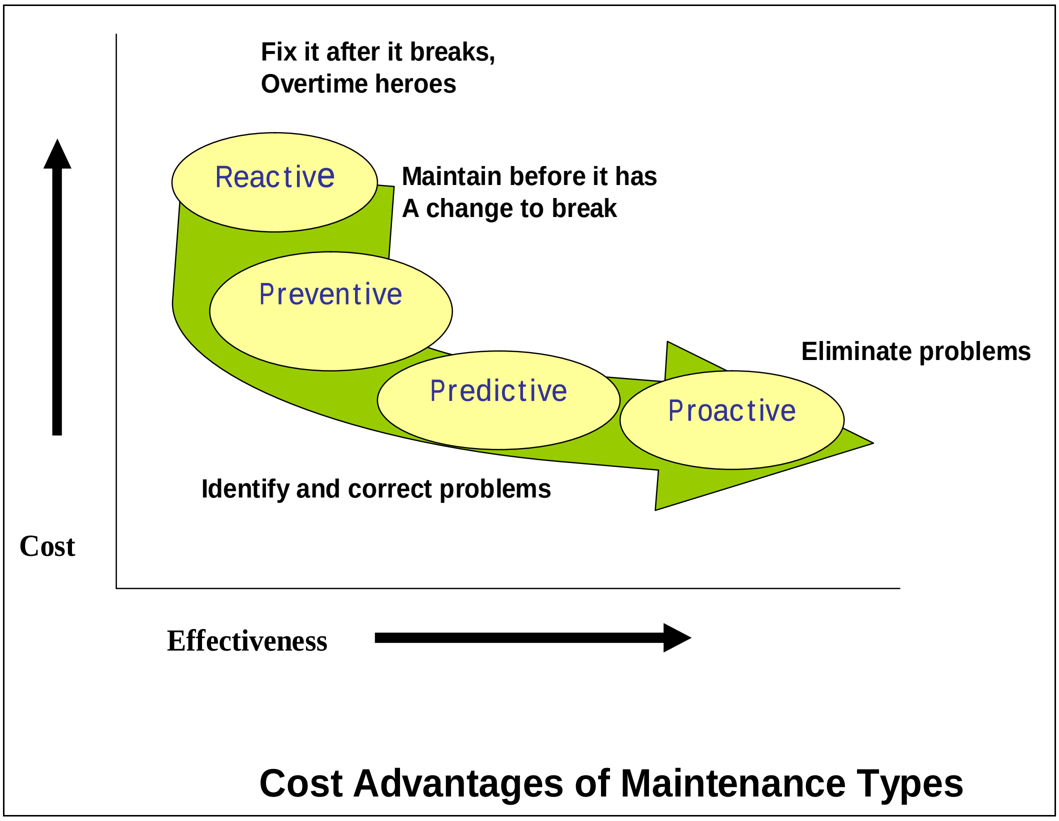
- Eliminate defects
- Stop machines from deteriorating
- Eliminate all preventive maintenance
- Reduce personnel
- Decrease lifetime maintenance cost

2.5.4 Proactive maintenance

This strategy concentrates on the monitoring of equipment performance and equipment health to prevent it from deteriorating to the point of brake down. The aim of this strategy is to extend the lifetime of equipment to the maximum and to take equipment out of service before it brakes down. A proactive maintenance approach can reduce maintenance expenditure, Figure 8.

Proactive maintenance begins with the identification of root causes of equipment failures and the initial application of acceptable engineering standards (Mitchell J.S, 2002).

FIGURE 8 - Cost advantages of maintenance types



Mitchell J.S, 2002:49, Physical Asset management Handbook

To gain maximum effectiveness and optimum maintenance cost it is necessary to move from phase to phase, through the defined phases in Figure 8, from a reactive to a proactive maintenance approach (Mitchell J.S, 2002).

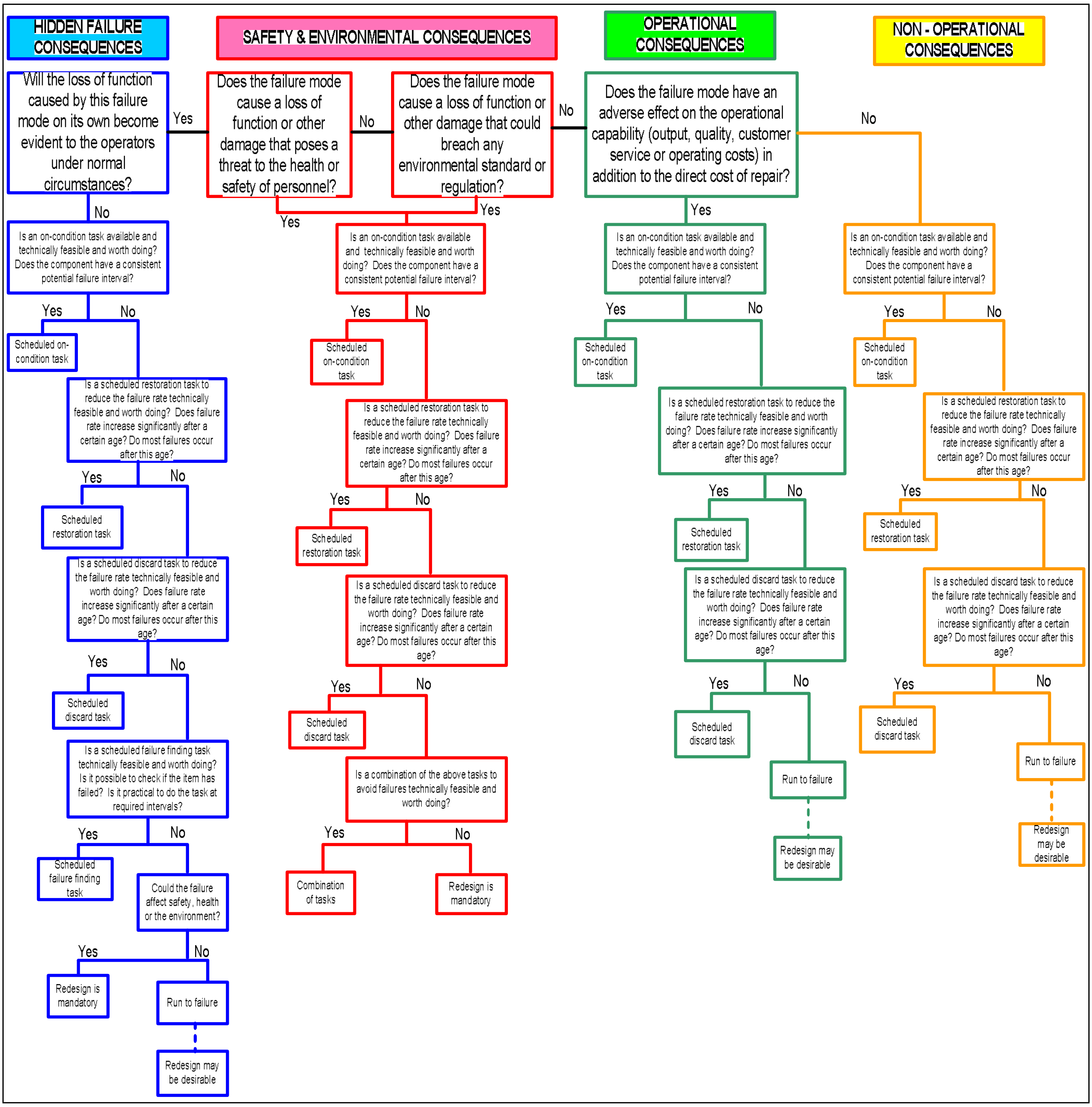
2.6 Reliability Centered Maintenance (RCM)

In the past few years a growing interest has emerged in the field of Reliability Centred Maintenance (RCM). Being originally developed for the airline industry, RCM is a structured process to determine the equipment maintenance strategies required for any physical asset to ensure it continues to fulfil its intended functions in its present operating context.

Therefore, the goal of RCM is to determine the critically equipment in any process, and based on this information, design a customized preventive/predictive maintenance strategy for that specific equipment. RCM initiatives however involve a tremendous amount of resources, time, and energy. Thus the RCM process is extremely time consuming and expensive especially when done according to the textbook (Levitt J, 2005).

The RCM process is only one tool to determine the appropriate strategy to limit the risks to the company, environment, community, operations or the health and safety of its employees (Levitt J, 2005). The following RCM decision diagram, Figure 9, must be applied to all machinery and processes. This decision diagram evaluates the consequences of hidden failures, safety and environmental impacts, operational and non – operational consequences.

Figure 9 - RCM decision diagram



Lochner T. (2006). *RCM in support of maintenance strategy revision.* Presented at the meeting of engineering managers of all Sasol, Sasolburg based business units held in Sasolburg.

2.7 Overall Equipment Efficiency

Overall equipment efficiency (OEE) is the product of normalized availability (Uptime), production throughput (Yield), first run quality and cost per unit (Mitchell J.S, 2002:87). The maintenance strategy applied to equipment must increase scheduled work and reduce emergency, urgent and any form of unscheduled work. The physical asset management process must be driven top down and accomplished bottom up (Mitchell J.S, 2002).

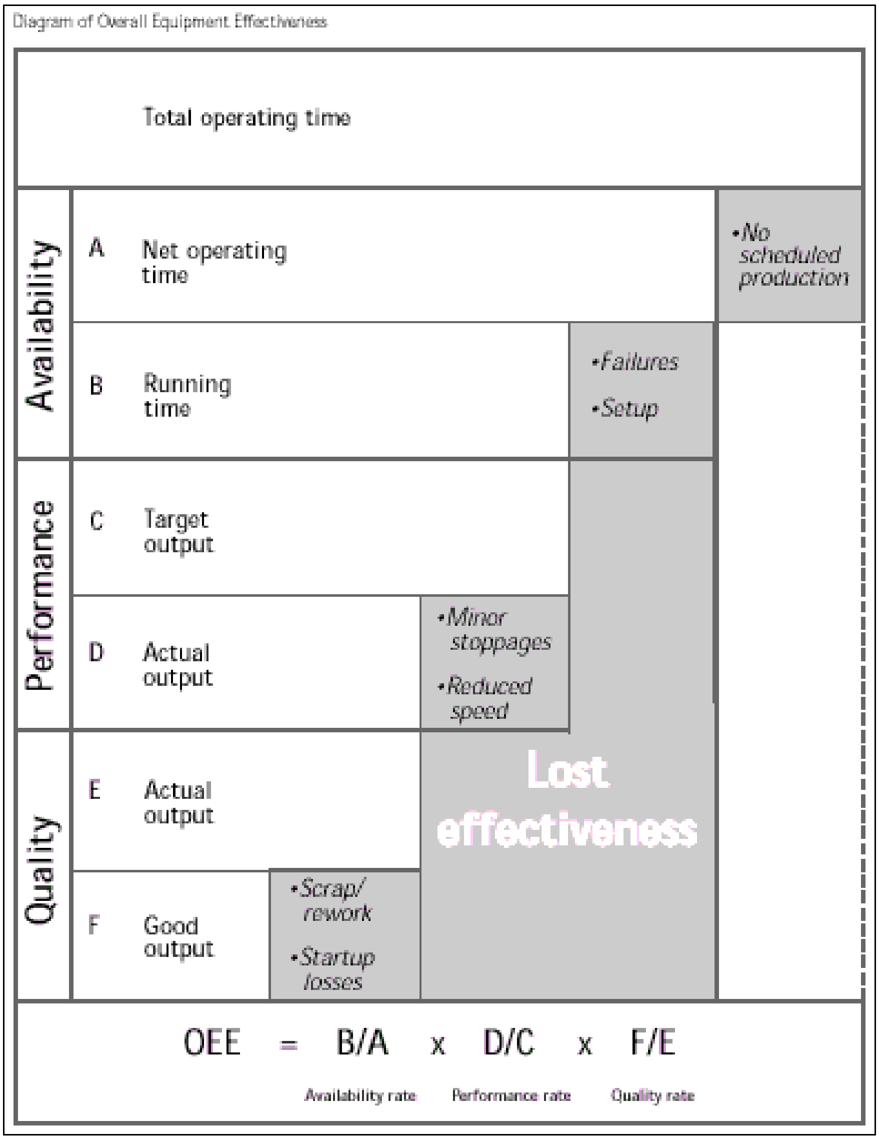
When equipment maintenance strategies have been developed and implemented, it must be measured. The overall equipment efficiency measurement can be used to evaluate if the current strategy is fit for purpose. Essentially, OEE offers a measurement tool that helps identify the real areas of opportunity within an operation. These areas are termed the "six big losses." The OEE measurement allows the user to break up the possible losses into smaller components to do better evaluation of the impact of these losses.

The six losses are:

- Breakdowns from equipment failure (unplanned downtime)
- Setup and adjustments from product changes and minor adjustments necessary to get the equipment operating properly after the line change
- Idling and minor stoppages due to abnormal operation of the equipment causing momentary lapses in production, but not long enough to track as downtime
- Reduced speeds, the discrepancy between design and actual speed the equipment operates
- Process defects due to scrapped production and defects needing rework
- Reduced yield and lost materials during the manufacturing process, from start-up to end of production run

Companies with an OEE of 85 percent or more, is considered to have world class performance (http://www.oeetoolkit.nl, Accessed 11 January, 2009).

FIGURE 10 - Components of Overall Equipment Efficiency (OEE)



http://www.oeetoolkit.nl, Accessed 11 January, 2009

Figure 10 illustrated the bottom-line good output is only a fraction of what it could be if losses in availability, performance, and quality are reduced. The diagram also suggests that to maximize effectiveness, to grow the good output on the bottom line, not only quality losses must be reduced, but also availability and performance losses. These three factors work together, and the lowest percentage is usually the constraint that most needs addressing (Levitt J, 2005).

It is recommended that the operator collect the daily data about the equipment for use in the OEE calculation. Collecting this data will (http://www.oeetoolkit.nl, Accessed 11 January, 2009):

- teach the operator about the equipment
- focus the operator’s attention on the losses
- grow a feeling of ownership of the equipment

The shift leader or line manager is often the one who will receive the daily operating data from the operator and process it to develop information about the OEE. Working hands on with the data will (http://www.oeetoolkit.nl, Accessed 11 January, 2009):

- give the leader/manager basic facts and figures on the equipment
- help the leader/manager give appropriate feedback to the operators and others involved in equipment improvement
- allow the leader to keep management informed about equipment status and improvement results
- Identify future expenditure and upgrade needs

Overall Equipment Efficiency (OEE) is a measure comparing how well manufacturing equipment is running compared to the ideal plant and design parameters.

OEE = Actual output / Theoretical maximum output

2.8 Maintenance ratios

The following are maintenance measurement ratios that can be evaluated against international standards (http://wwwfindarticles.com, Accessed 12 January, 2009).

2.8.1 Maintenance material cost as % of total sales

This ratio measures the maintenance material cost as a percentage of the total sales. World class minimum is 1.5% and maximum is 2.8%. This measurement must be used as an average over a period of time to include major shutdown and repair activities.

2.8.2 Maintenance cost as % of total sales

This ratio measures the total maintenance cost, labour and material included, as a percentage of the total sales. World class minimum is 1.5% and maximum is 5%.

2.8.3 Maintenance labour cost as % of total maintenance cost

This ratio is an analysis of the percentage labour cost of the total maintenance expenditure. World class minimum is 10% and maximum is 40%.

2.9 Planning and materials management

2.9.1 Work identification

Work identification is the result of the maintenance strategies that was developed for all the equipment within the specified process. The appropriate maintenance strategy is used to develop a preventive maintenance plan and to determine scheduled maintenance activities with the goal to increase the life and performance of an asset (Levitt J, 2005). Planned maintenance is maintenance that is scheduled in advance with a specific lead time. The measurement of productivity based on planned maintenance activities will optimize the engineering department performance (Mitchell J.S, 2002).

2.9.2 Failure analysis

A method to verify if the selected maintenance strategy is applicable to a piece of equipment, is Root Cause Failure Analysis (RCFA), and is based on failures that have occurred in the past and the overall effect on the business is known or anticipated (http://www.maintenanceresources.com, Accessed 14 January, 2009. RCFA ensures that a proactive measurement is taken to manage a failure. Most costs associated with conducting RCFA are in people's time and resources to verify findings and to give trustworthy information.

RCFA is a disciplined vertical problem solving methodology used to determine levels of root causes of specific failure events (Levitt J, 2005). The following process is necessary to implement a successful RCFA effort:

- Prioritize – Determine what is most important to work on
- Analyze – Analyze the failure event to determine root causes
- Recommend – Develop recommendations and solutions to the causes discovered

The RCFA supports the Six Sigma process. Mitchell J.S. (2002:79) states that there are eight phases to a Six Sigma project are:

- Project definition – a project must be quantified and have realistic boundaries
- Map the as-is process
- Define the process inputs and outputs

- Process measurement – gather data including the number of defects
- Process analysis – analyze the test failure occurrences and modes
- Process improvement
- Validate improvement – key variables are identified above are tested using design of experiments and other techniques
- Process control – improvements are sustained and institutionalized so that backsliding does not occur

2.9.3 Prioritizing

Priority means "coming before in time, order, or importance" (http://www.franklin.com). When prioritizing maintenance work it must be based on facts and acceptable engineering principles. By applying acceptable engineering principles, emotions will be eliminated from the prioritizing process.

Emotional priorities are based on individual or group needs within a working environment and does not take into account the needs of the entire business. These are the typical requests that are not logged official with a notification but rather verbally or while passing by. The reason for this behaviour can also be because the requester does not want to load a priority 1 or 2 works order as this can be reflected to that individual as being negligent. This type of behaviour must be changed to move from being in a reactive mode to a planned and scheduled environment. When events can be planned control over those events can be exercised.

Prioritizing work must take into account the following, in no order (Levitt J, 2005):

- Risk to injury
- Risk to environment
- Business risks

- Resulting costs if not taken immediate action
- Production losses
- Reputation damage

2.10 Maintenance Planning and Execution

To be able to do proper planning, work orders (requests) have to be generated using the computerized maintenance management system (CMMS) (SAP R/3) system. These works orders are combinations of the maintenance strategies and maintenance requirements notifications must be loaded on the CMMS. In this dissertation work orders are also referred to as notifications. These notifications can be as a result of inspection by operational or engineering personnel or as a result of equipment not running within the design parameters. These requests can be referred to as unplanned maintenance. This includes emergency and urgent work that is required and sometimes priority 3 or planned work. Emergency work is defined as priority 1 work and this type of work must start immediately and must continue until the work is completed.

World class performance for this type of work order is between 0% and 5% of the total works orders within a defined time, normally measured in weeks (http://www.samicorp.com, Accessed 21 February, 2006). This type of work must be at a maximum of 15%. The reduction of priority 1 work will reduce call-outs and other schedule breakers. Because priority 1 work is unanticipated failures, these are failures where RCFA studies can be conducted to ensure that problems are understood and eliminated.

Factors that affect the amount of emergency work are (Mitchell J.S, 2002):

- The current state of the production unit and machinery
- The willingness of production and maintenance personnel to create a notification if they are aware of any problem
- Discipline of personnel to assign the correct priority to works orders
- Quality of inspections
- Quality of equipment maintenance strategies
- Operating parameters

Urgent work is defined as priority 2 work and must start within 7 days. World class for this type of orders is below 10% (http://www.samicorp.com, Accessed 21 February, 2006).

The scheduling of tasks start when the required work orders are populated within a specific time and period, and balanced with the available man hours. A target of 80% available capacity planning is acceptable (http://www.samicorp.com, Accessed 21 February, 2006). This allows time for training, breaks and safety talks. In order to manage the efficiency of the planning system key performance indicators must be measured and trended. The following six indicators will ensure that the maintenance department is optimally utilized (Hedding R, 2005).

2.10.1 Percentage Emergency (Priority1) Work Orders

This type of work is classified as reactive and interrupts the daily schedule. Priority 1 work starts immediately and work will continue until completed. Call-outs are also classified as priority 1 work. Word class maximum for this type of works orders is 5% of the total amount of works orders (http://www.samicorp.com, Accessed 21 February, 2006) and is an existing tool in use in the explosives manufacturing plant.

2.10.2 Percentage Urgent (Priority 2) Work Orders

This type of work will start within 7 days but not on the same day as the notification date. This type of work will therefore not interrupt the daily schedule. Word class maximum for this type of works orders is 10% of the total amount of works orders (http://www.samicorp.com, Accessed 21 February, 2006) and is an existing tool in use in the explosives manufacturing plant.

2.10.3 Percentage Schedule Compliance (Hours)

This is expressed as a percentage of completed scheduled work orders. This is an indication if the maintenance department completed the planned work. In combination with resource loading this measurement will identify that more (or less) work was performed by the department measured against the planned work. This measurement is a weekly snapshot of what work was scheduled vs. what work was completed, and no credit is given for partially completed work. The maximum score can therefore be 100%. If planned work is executed according to the planning schedule, there will be less dependence on contractors and the need to perform overtime work. If schedules are complied too services and materials can be purchased more cost effective as the activities are planned and the lead times are known to all parties involved (http://www.samicorp.com, Accessed 21 February, 2006).

2.10.4 Capacity Planning (% Schedule Loading – Hours)

The aim of capacity planning is to optimize the available hours of the workforce, and to assign scheduled tasks to that available time. The scheduled hours must be at 80% to allow for urgent and emergency work (http://www.samicorp.com, Accessed 21 February, 2006).

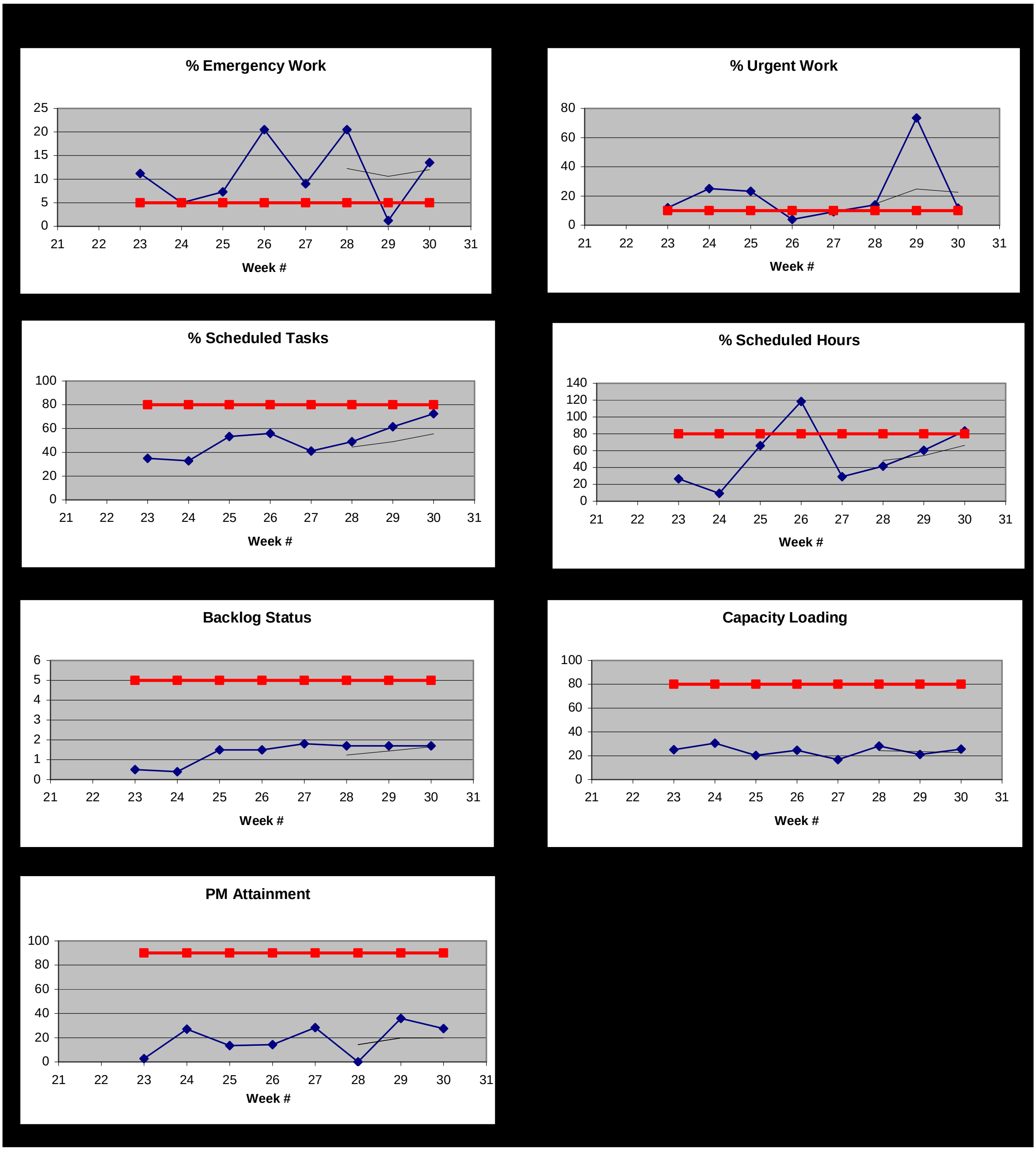
2.10.5 Backlog in Crew Weeks

This is the amount of scheduled work looking 7 weeks ahead. World class performance is between 5 and 7 weeks. This value will indicate if the maintenance team is over or under staffed and is also an indication of the effectiveness of the current maintenance strategy. Too low a backlog can encourage tradesmen to stretch work or to work ineffectively to avoid reduction of manpower. Too high a backlog will cause the customer to suffer delays for routine work requests (http://www.samicorp.com, Accessed 21 February, 2006).

2.10.6 Preventive Maintenance Schedule Compliance

This measurement is a snapshot taken every week on the same day and time. It measures the completed amount of scheduled work and compares this to what was planned. The maximum score therefore is 100%, Figure 11. A low score indicates that the maintenance schedules are not done and that there are many schedule breakers. It can also indicate that work orders were not closed for a variety of reasons including waiting for spares or specialized services. This data must be analyzed continuously (http://www.samicorp.com, Accessed 21 February, 2006).

FIGURE 11 - Graphical representation of engineering performance indicators for the Prillan explosives manufacturing plant, week 23 to week 30, 2007



SAP R/3, WEEK 23 - 30, 2007, RETRIEVED 16 JULY 2008

2.11 Work Execution Review

This process is designed to review work executed and is in the form of a weekly meeting between the engineering and operational personnel. Unplanned downtime is reviewed and the real cause of failures must be investigated (http://www.samicorp.com, Accessed 21 February, 2006). Standard time to execute work must be updated to ensure that the available man hours are known to perform similar activities in future. The data available on the CMMS network must be regularly reviewed to ensure the integrity of the data. This data can be updated after failure analysis and the following techniques can be used to determine the real causes of failures:

- Failure mode and effect analysis (FMEA)
- Fishbone or Ishikawa diagrams
- Histograms
- Process maps
- 5 Why's (Ask five times why)

2.12 User Status Management

A tool within the SAP CMMS system is the monitoring of user status. This identifies the work order by the status within the planning and execution cycle. The user status identification ensures that the planner and management can focus on the reason the work order is not closed on the planned date and includes waiting for:

- Spares
- Quotations
- Invoices
- Specialized skills or equipment
- Documents or procedures

Overdue work orders must be reviewed weekly to determine the status of these work orders. Open work orders are work orders that can not be closed for mainly two reasons, the work order has not been technically completed or the work order has not been financially completed. These orders are updated with a user status to indicate why the work order has not been completed.

This user status can include:

- WCAN - Work was cancelled
- REFU - Refurbishment Item
- WFEQ - Waiting for equipment
- WFMT - Waiting for material
- WFSR - Waiting for service provider
- CWIV - Waiting for invoice
- EQNA - Equipment not available
- WIPR - Work in progress
- JCPA - Job complete, planner action

SAP has the functionality to display these open orders graphically. Overdue open work orders are open orders that have exceeded the planned completion date and are available on IW38 function on SAP P/3. This can be displayed per engineering function as well as per service provider. This must be managed to ensure that work that has been completed is paid for and also ensure that service provider efficiency is managed. Examples are:

FIGURE 12 - Overdue open work orders for planner group A08 on 2008-08-13

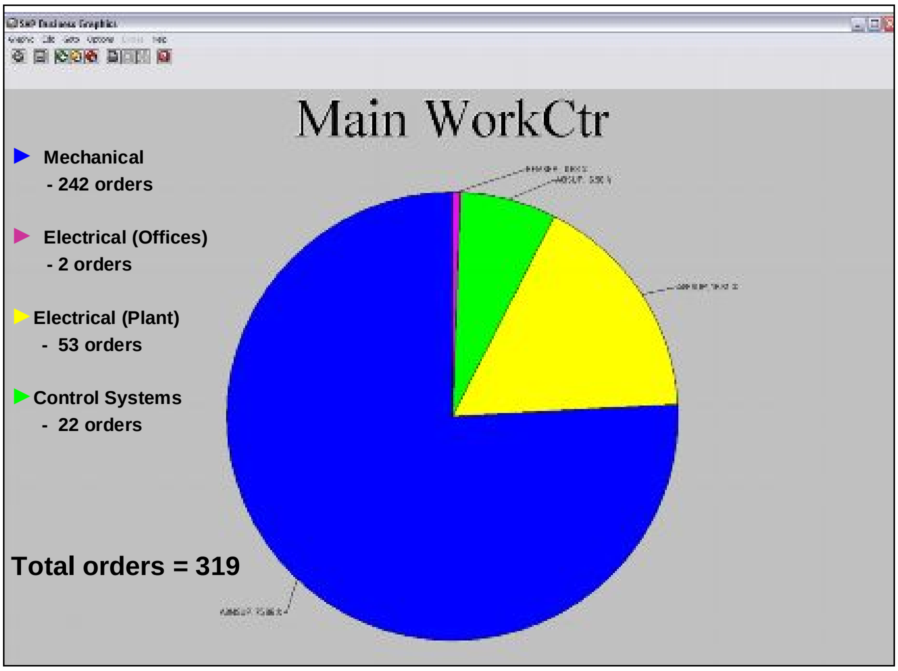


Figure 13 displays all the overdue open work orders for a specific planner group or plant. This tool can be used to track overdue open orders per engineering discipline.

FIGURE 13 - User status for overdue open work orders for planner group A08 on 2008-08-13

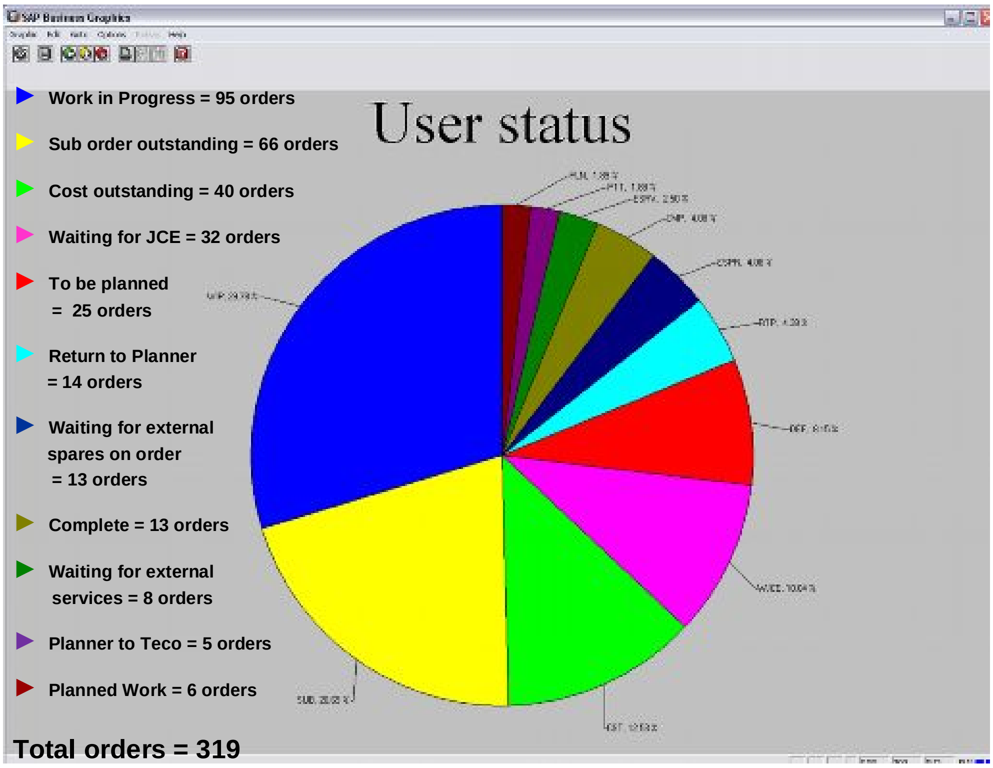


Figure 14 displays all the overdue open work orders for a specific plant and indicates the reason why it is still open according to the user status. This tool can be used to manage service providers and to evaluate work that is in progress.

FIGURE 14 - Supplier detail and rand value for overdue open work orders for planner group A08 on 2008-08-13

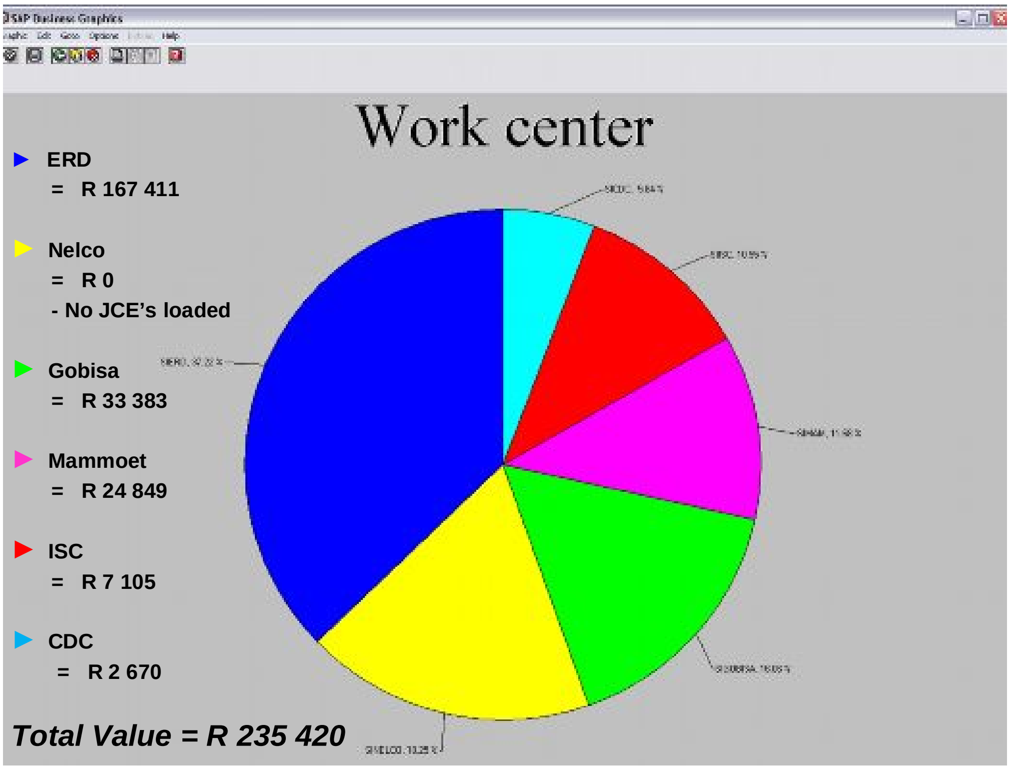


Figure 14 displays the overdue works orders monetary value and can be used to do accurate financial forecasting and to manage expenditure.

2.13 Balanced Scorecard

Roles and responsibilities must be defined for the following processes (http://samicorp.com, Accessed 21 February 2006):

- Meetings
- Works order execution, feedback and closure
- RCA evaluations and execution
- Planning and scheduling
- Reporting responsibilities

These roles and responsibilities must clearly define who are Responsible, Accountable, Consult and Inform (RACI). A balanced scorecard can be designed to measure the required outcome per function and per an individual. The balanced scorecard links a company's long term strategy to short term actions. Mitchell J.S, (2002:80-b) states that there are eight keys related to balanced scorecard success:

- Balanced scorecard must be an integral part of the change process
- Strong, visible executive sponsorship
- Greater focus on long-term objectives
- Build teamwork and align objectives
- Measure results
- Direct attention to factors that drive measures and results
- Recognize that learning is an evolutionary process
- Connect compensation to scorecard results

2.14 Materials Management

A recent audit was conducted on the accuracy of spares as indicated on the SAP PM system. The method used was to compare the actual spares kept in the stores, to that which was indicated on the SAP system. The results reflected that the information at hand is not trustworthy and that some of the descriptions of item specifications were not described to an acceptable and understandable standard to avoid confusion. A successful strategy must clearly indicate what spares are critical to the process and what inventory must be kept.

Materials management deals with the logistics within all the components of the supply chain. This includes sourcing, acquisition, quality control and the replacement of spares and consumable items. Materials management can be broken down into three areas (Mitchell J. S, 2002):

- Acquisition
- Quality control
- Standards

Many people and organizations refer to the management process of materials into two categories, pulling and pushing (http://www.eventhelix.com, Accessed 20 January 2009). The pull system is based that when stock is used or required, it is replenished. The push system is a more scientific approach to ensure that stock is available and includes stock of high monetary value and that is not easy available.

Materials management can be designed around the environment it serves. Just in time (JIT) delivery of the correct item is the objective of every materials manager (Levitt J, 2005). The basics of stock keeping are to ensure that stock is replaced when it is used. It is of importance that the integrity of the stock items be ensured and that it complies with the required standard.

Stock levels must be controlled and for this control there are various control measures:

2.14.1 Visual Control

This is the most common practice and material is replaced when the stock level is observed to be low (Mitchell J.S, 2002).

2.14.2 Vendor Managed Inventory/Vendor Out Stock

This is when the supplier manages the customer's inventory. This is usually based on the Kanban system where the supplier manages the stock levels on behalf of the customer as a value added service (Mitchell J.S, 2002).

2.14.3 Consignment Stock

This is a very good method to ensure that stock is available without having inventory on the business balance sheet. This also reduces the risk of the customer if there are changes in the product that is used as the obsolescence in the event of change is for the account of the supplier (Mitchell J.S, 2002).

2.14.4 Smart Systems

Stock and inventory can be managed by the use of smart systems such as bar coding. These systems can be connected to the suppliers and replenishment can be done remotely.

Materials management includes the ability to comply with all health and environmental legislations and must be able to handle the equipment stored without damage and comply with the equipment manufacturer recommendations. This includes the segregation of material, climate control, and adjustment of material positions as in the case of large bearings to prevent pitting and many more (Mitchell J.S, 2002).

2.15 Engineering Workforce

The success of the revision and implementation a maintenance strategy depends on people. For this reason the existing performance and activities of the engineering team must be defined. The leadership attributes must be established and a change management model is needed. Most organizations operate with traditional organizational structures and this is creating limitations to the individuals (Harrington J.H, 2004). These limitations include functional barriers and organizations justify this by imposing tertiary qualification requirements for certain positions. Self directed work groups can be established where people with different functions and responsibilities can interact with no limitations imposed on them and where the required results are defined and measured (Kelly A, 2001).

The key focus area becomes the sharing of knowledge and supporting other disciplines rather than only performing within a defined functional discipline. Self directed work group organizations are focused on partnerships and continuous improvement and development of the plant and individuals within that group. This has specific reference to the "production/maintenance" interaction. People with different functional responsibilities must see themselves as partners in a team charged with a common goal. Management should stay involved during the strategy revision process and create a change platform (MAC Consulting, 2008). This change platform must be used to get all role players together to share ideas and can take the form of meetings or workshops. Involvement of all levels within the organization creates trust and promotes the sharing of knowledge.

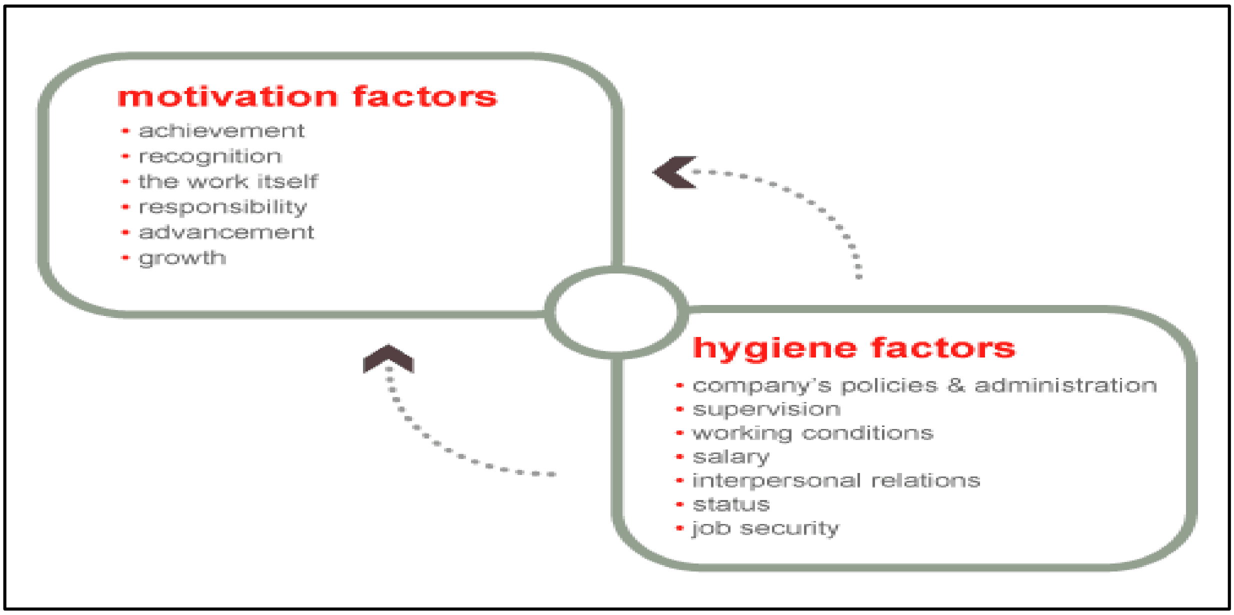
Roles and responsibilities must be defined and accountability must be understood and accepted. It is important to ensure that strategic, tactical and operational issues are addressed

9Pretorius H, 2007). To be able to perform to the required standards within an assigned role the individual or group must have the required depth and range of know how to have the desired impact on the organization. Gaps within groups and individuals must be identified and addressed by development programmes and training. On all levels the communication and influencing skills of the people must be continuously developed (Daniels A.C, 2004). A challenging environment must be created to ensure that there is an environment where people are required to think and enable them to act accordingly (Herzberg F, 1993).

Herzberg found that the factors leading to job satisfaction were separate and different from those leading to job dissatisfaction, hence the term “two-factor” model (Smit P.J and Cronje G.J, 2003). The sources of work satisfaction were termed “motivator factors” and include the work itself, achievement, recognition, responsibility and opportunities for advancement. These factors are related to the work content and are associated with a positive feeling about the job (Smit P.J and Cronje G.J, 2003). The factors that lead to positive job attitude do so because they satisfy the individual’s need for self-actualization at work (Suthmeister R, 1976).

The sources of work dissatisfaction were termed “hygiene factors” by Herzberg. These are factors in the job context and include working conditions, company policies, supervision, interpersonal relationships and salary. If these factors are adequately provided for in an organization, there will be no dissatisfaction. Hygiene factors are associated with the individual’s negative feeing about work and do not contribute to employee motivation (Smit P.J and Cronje G.J, 2003).

FIGURE 15 - Model of Herzberg's two-factor theory



Smit P.J and Cronje G.J, 2003

There can be for scenarios using the mode by Herzberg (http://www.12manage.com, Accessed 27 April, 2009):

- High Hygiene + High Motivation: The ideal situation where employees are highly motivated and have few complaints.
- High Hygiene + Low Motivation: Employees have few complaints but are not motivated. The job is perceived as a pay-cheque.
- Low Hygiene + High Motivation: Employees are motivated but have many complaints. A situation where the work is challenging but the salary and working conditions are not good.
- Low Hygiene + Low Motivation: The worst situation. Employees are not motivated and have a lot of complaints.

Mitchell J.S (2002:6) states that the culture change required for success will not occur without involvement of the management. The management skills of the explosives manufacturing plant can be evaluated with reference to their technical, management and people skills, Figure 15.

The following are management theories that influence the current and future organizational culture (Daniels A.C, 2004):

- Organizational design
- Group and individual objectives and targets
- Ownership and individual involvement
- Communication and Information
- Performance management
- People training and development, career paths for every individual
- Leadership and motivation
- Recognition and incentive
- Discipline

The following are attributes for a good/great supervisor:

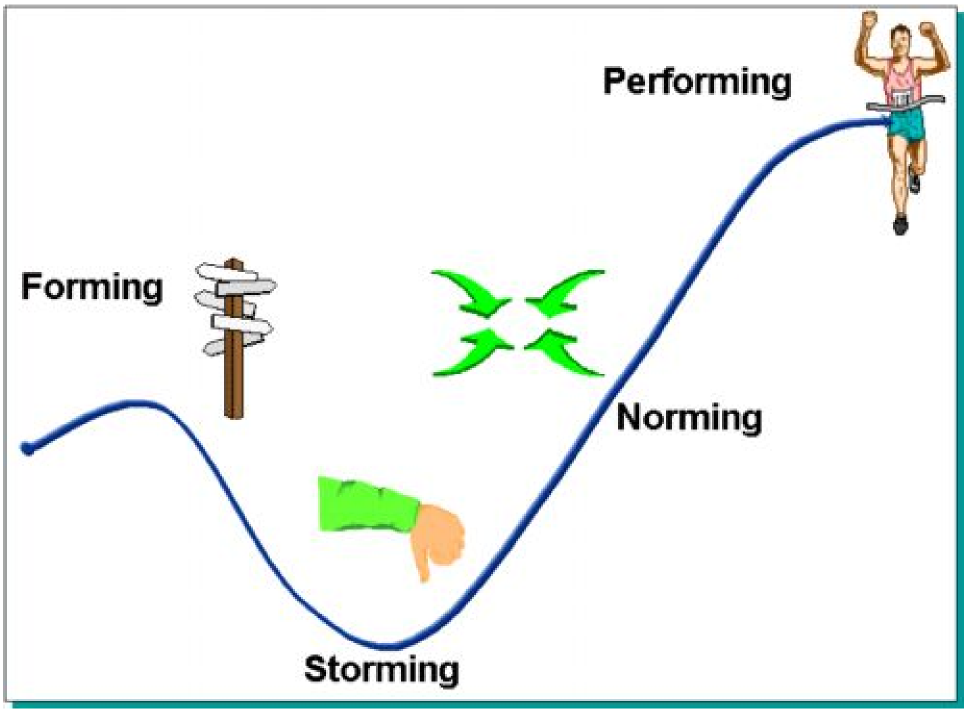
TABLE 1 - Attributes for a good/great maintenance supervisor

PEOPLE SKILLS	MANAGEMENT SKILLS	TECHNICAL SKILLS
Good listener	Is organized	Dedicated to quality
Compassionate	Can make decisions	Knows equipment
Motivator	Good delegator	Knows job
Fair and consistent	Meets goals of business unit	Knows safety
Respected	Can analyse progress to goal	Can analyze problems
Honest	Knows what is important	Can evaluate skill level
Effective trainer	Provides good customer service	Understands product
Open minded	Loyal to organization	
Effective communicator	Results orientated	
Coach, not dictator	Good planner	
Good negotiator	High productivity	
Has a cool head	Follow up	
Flexible	Can schedule	
Can handle pressure	Assign and keep priority	
Can read people	Understand and use budgets	
Adaptable to change	Is available	
Has common sense	Can communicate	
Willing to learn		
Positive outlook		
An innovator		
Praise in public		
Discipline in private		
Takes control if necessary		
Not afraid to make mistakes		
Treats people as equals		
Can work with different types of people		
Gives recognition for work well done		
Can deal with difficult people issues		

Levitt J, 2005:254

2.16 Change Management

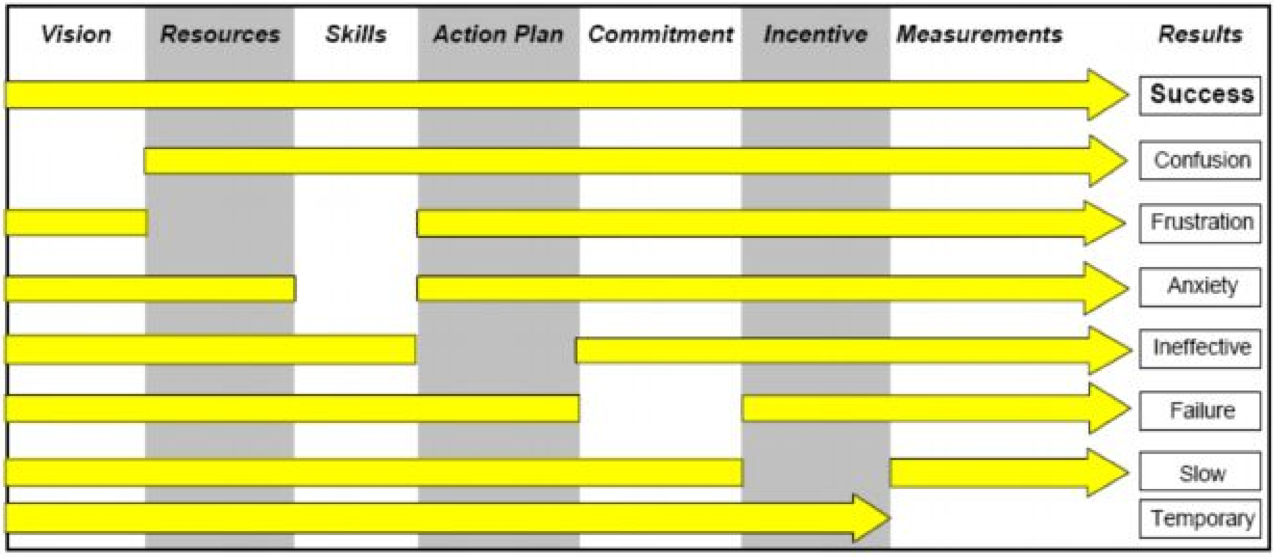
FIGURE 16 - Phases in the Change Process



Smit P.J and Cronje G.J, 2003

Figure 16 illustrates the phases in a change process (Smit P.J and Cronje G.J, 2003). Change is a process and the first step to change is for management to recognise the need for change (Smit P.J and Cronje G.J, 2003).When the need for change has been identified managers must clearly state the desired outcome of the change intervention. Third, the cause that necessitated the need for change must be diagnosed. When the cause to change is clear, the change process can be designed. The recommendations of this dissertation can be used as a change process and an implementation plan must be developed taking factors such as cost, skills and technology into consideration. After the change intervention is completed, it must be evaluated to determine of the change intervention was successful. This evaluation can indicate the need for further change initiatives.

FIGURE 17 - Change Management Model



Mitchell J.S, 2002:126

Figure 17 illustrates that for the successful implementation of an asset management strategy there must be a vision, resources, skills, action plans, commitment, incentive and measurements in place. A lack of vision will result in confusion. A lack of resources and skills will result in frustration. A lack of skills will result in anxiety. A lack of an action plan will result in ineffectiveness. A lack of commitment will result in failure. A lack of incentive will slow down the process. If the process is not measured, the implementation of this strategy will be temporary.

2.17 Chapter Summary

In Chapter 2 the fundamentals of asset management models were researched and the elements of these models include maintenance strategies, materials management, prioritizing and planning. Commonalities between these asset management models are:

- Equipment knowledge
- Spares accuracy
- Scheduled maintenance replacements
- Visual asset performance measures
- Technical training and development

Various maintenance strategies are evaluated and compared to its cost advantages and applicability to equipment. These strategies range from breakdown maintenance to proactive maintenance depending on the effect of failures on the safety and integrity of the plant as well as the operational consequences. It is stated that Asset Management is a combination of all these maintenance strategies. RCM can be used to determine the applicable maintenance strategy per equipment or process to ensure that the equipment continues to fulfil its intended functions in its present operating context. The OEE measurement identifies six losses within its calculation. These are factors that influence quality, performance and availability. The overall equipment efficiency measurement is a comparison between the actual plant performance and the ideal plant. It is highlighted that the total asset management process is a combination of planning, materials management and supervisory and management attributes and involvement. Overdue work orders are often difficult to manage and the user status functionality on SAP R/3 can display a graphical representation thereof to do financial, service provider and engineering management. The use of user status indicates the need for engineering personnel to fully understand and use the CMMS system in use and the need for discipline to update the status of works orders.

To develop tools to improve the wrench time of artisans the activities performed by these people is mapped by using the DILO technique. DILO's indicate the actual time spend by artisans to perform various tasks that reduces the available time for actual wrench or spanner time. The revision of the maintenance strategy using asset management principles requires objectives and targets for all involved in this process. A balanced scorecard can include these objectives and targets per individual and functional areas to ensure that the business and individual's strategies are aligned.

The revision of a maintenance strategy involves people and can not be effectively executed without change management interventions. The motivators and hygiene factors from the theory of Herzberg provide for a basis to ensure that employees are motivated and experience job satisfaction. The organizational culture, leadership attributes and available skills impacts on the change management process. The change model must clearly indicate the need for change, required.

CHAPTER 3 – EXPERIMENTAL WORK

3.1 Purpose and Chapter Outline

The purpose of this chapter is to verify the merit of this research topic by using interviews and questionnaires and to establish if there is a need to focus on any of the five commonalities of asset management models defined in Chapter 2. These five commonalities are scheduled maintenance replacements, spares accuracy, equipment knowledge, visual performance indicators and technical training and development. The information gathered from this experimental work can be used to identify the barriers that must be removed to increase the proactive work capacity index and overall equipment efficiency (OEE).

In this chapter a correlation between these commonalities is calculated to provide the management of this plant with direction for prioritizing the actions required to revise the maintenance strategy. The implementation of these actions will increase the OEE of this plant.

3.2 Study design - Target Population and Study Sample

The method for collecting data on this manufacturing plant was interviews and questionnaires. Interviews and questionnaires were used to gather plant specific results and to tap into the specific knowledge of these employees. Questionnaires ensure that the opinion of the people that are directly impacted on by this research is gathered. Structured interviews allowed for direct contact with employees. The same questions were asked to all interviewees to ensure that data collected are consistent.

The engineering team reporting directly within the structure of this manufacturing plant is mainly responsible for the day to day repairs and inspection of non specialized activities. Specialized activities, such as preventive, predictive and condition based maintenance are performed by a team reporting to a service provider. The service provider engineering team as well as most of the plant personnel that were not interviewed were tasked with a questionnaire to gather valid and reliable data.

3.3 Interviews

This target audience for interviews consisted of the following individuals:

- Production manager,
- Engineering manager,
- Maintenance artisan,
- Production operator,
- Maintenance operator

This group of people was selected to get the opinion of people that perform the engineering service as well as the customer of the engineering department. A combination of the information obtained will present a balanced reflection of the magnitude and accuracy of the current engineering and equipment performance requirements within this plant.

3.4 Interview Questions:

The aim of the questions of the interviews is to determine the need to focus on the five asset management commonalities and to prioritize the required focus areas.

Primary question:

How efficient is the current maintenance strategy for the explosives manufacturing plant, what must be changed and how must it be changed?

The aim was to set the scene to highlight the views of the interviewed people on the current state of the business with specific reference to the engineering department. The primary question was followed by the following specific and structured questions:

1. **What is meant by "Asset Management"?** This question really tested the person's understanding of the term and basic understanding of the concepts used in this study.
2. **What are the skills required by people in your organization to improve equipment reliability?**
3. **Can the efficiency of the maintenance crew be increased?**
4. **Will a change in the current maintenance strategy improve the equipment reliability?**
5. **What are the typical softer issues engineering personnel are faced with?**
6. **What change management techniques will work in your organization?**

3.5 Raw Data Collected

From the questions posed to the candidates, the following is a summary of the responses:

3.5.1 Respondent #1 – Production Manager

This respondent had a good practical understanding of asset management. He included normal, scheduled and replacement maintenance activities as well as people in his definition of asset management. He added the need to measure asset performance such as MTBF results of pumps and plant availability (Visual performance measurements D).

It is his opinion that inspections are done by engineering personnel but that they do not always know what to look for (Technical training and development E). This may be due to a lack of equipment technical information and performance requirements (Equipment knowledge A).

He feels that there must be a focus on reliability projects and that more work can be scheduled (Scheduled maintenance replacements C). It is his opinion that a re-organisation of manpower is needed as the maintenance crew is unnecessary large to cope with breakdowns where a lot of personnel are needed. He confirmed that the current spares holding philosophy is not working and that the description of spares is not correct (Spares accuracy B).

It is his view that the plant reliability can be improved by keeping to production schedules as prepared by the marketing personnel and by analyzing data available from history on plant interruptions. He stated that not all the engineering managers are actively involved in the plant activities and not all the engineering people know the effect of off-specification product on the business. He requested alarms on remote equipment to eliminate breakdowns.

3.5.2 Respondent #2 – Engineering Manager

This respondent had an excellent understanding of asset management and the need to monitor performance and the ability to react on trends and information. He mentioned the management and measurement of overall equipment efficiency, downtime, overtime, strategies and the out engineering of breakdowns and equipment failures (Visual performance measurements D).

He expressed the need to re-train artisans and to develop fault finding techniques (Technical training and development E). He also mentioned the need to get equipment “footprints” to build up equipment performance history. Document control must be developed to make this initiative successful.

It is his view that the plant reliability can be improved by doing planned replacements (Scheduled maintenance replacements C), and by eliminating stop-starts. There was a perception that the plant is not always operated within design parameters and that there is a need to invest in new technology. He mentioned that the spares are not always correct and that there is a need to form partnerships with spares suppliers to gain technical knowledge (Spares accuracy B).

3.5.3 Respondent #3 – Maintenance Artisan

This artisan has the opinion that asset management is the management of all assets and those assets can be defined as anything that can generate an income or has monetary value.

It is his opinion there is a shortage of manpower and that the load sharing per individual artisan is not done correctly. This again referred to the planning of activities.

He feels that more planned shutdowns and the co-ordination of spares (Spares accuracy B) will improve the plant reliability. There are too many items that have no strategy and are run to failure (Scheduled maintenance replacements C).

3.5.4 Respondent #4 – Production Operator

This operator had a good understanding of the asset management concept. He referred to asset management as the management of assets and included maintenance, cash flow and investment management and the improvement of the environment and safety systems.

It was his opinion that the required skills to improve the reliability of equipment must start with task observations by qualified people that knows the process and activities performed on the plant (Equipment knowledge A). It was his concern that such a system is in place but the responsible observers do not spend enough time on the plant. The reliability of the equipment can also be improved if roles and responsibilities are clearly defined and if defects are reported immediately. Training on the process to report defects is a limiting factor (Technical training and development E).

It is his concern that the planning of tasks during no production time is not done effectively and that certain tasks need more than the allocated people for that task. Because the equipment in use is big and heavy, one artisan per trade on standby, especially mechanical, is not enough to repair breakdowns and lead to excessive downtime. It is his opinion that some of the equipment in use has reached the end of their lifetime and need to be replaced with new and more reliable technology (Scheduled maintenance replacements C).

3.5.5 Respondent #5 – Maintenance Operator

This operator had the understanding that asset management is only about repairing equipment that failed.

It is his opinion that planning skills must be developed. This has a specific reference to the availability and compatibility of spares. He calls this “spares ordered are sheep and what arrives are sheep mixed with dogs” (Spares accuracy B). This is especially dangerous as the product is explosive and can not be contaminated by certain products such as oil. He feels that there must be less emphasis on tertiary qualifications when people are employed and that the focus must rather be on whether that person has the required functional talent (Technical training and development E).

It is his opinion that the plant reliability can be improved if there are more maintenance personnel employed to ensure that tasks performed are not done in a hurry that leads to more failures and unplanned downtime (Scheduled maintenance replacements C). Plant operators must be trained to do first line maintenance (Technical training and development E).

TABLE 2 - Interview summary, focus areas to establish an asset management culture

	Equipment knowledge A	Spares accuracy B	Scheduled maintenance replacements C	Visual performance measurements D	Technical training and development E
Production manager	**X**	**X**	**X**	**X**	**X**
Engineering manager	**X**	**X**	**X**	**X**	**X**
Maintenance artisan		**X**	**X**		
Production operator	**X**		**X**		**X**
Maintenance operator		**X**	**X**		**X**

Table 2 indicates the answers obtained from the interviews and are marked with X to indicate the link with the commonalities of asset management.

3.6 Questionnaire population and justification

Table 3 is a summary of the response to the questionnaires. The questions all refer to a specific common element of asset management and are referred to as commonality indicators.

The following commonalities were used in the questionnaire:

A – Questions related to equipment knowledge

B – Questions related to spares accuracy

C – Questions related to scheduled maintenance replacements

D – Questions related to visual performance measurements

E – Questions related to technical training and development

3.6.1 Validation of questionnaire

The questionnaire was send to four engineering departmental managers to validate if the questions asked are linked to the commonality indicator as indicated in Table 3. These engineering disciplines included:

- Electrical engineering manager, Louw, A.B. (nick.louw@sasol.com). (11 August 2009). *RE: Questionnaire validation.* E-mail to Bango, B. (lourence.bango@sasol.com).
- Instrumentation engineering manager, Louw, A.B. (nick.louw@sasol.com). (11 August 2009). *RE: Questionnaire validation.* E-mail to Weber, E. (ettiene.weber@sasol.com).
- Mechanical engineering manager, Louw, A.B. (nick.louw@sasol.com). (11 August 2009). *RE: Questionnaire validation.* E-mail to Erasmus, H.J. (Hannes.Erasmus@sasol.com).
- Planning and scheduling manager, Louw, A.B. (nick.louw@sasol.com). (11 August 2009). *RE: Questionnaire validation.* E-mail to Van Zyl, B. (ben1.vanzyl@sasol.com).

Correspondence received from above mentioned managers confirmed the interpretation and question linkage to the common indicators as indicated in Table 3.

Common Element A, Equipment Knowledge

The questions grouped under A have specific reference to Equipment knowledge.

Questions related to A:

- Are repetitive equipment failures investigated? (Question 2)
- Is root cause analysis being done to fix the problems and not only the symptoms? (Question 6)
- Are equipment repaired within planned time? (Question 11)
- Are drawings and specification up to date for critical equipment? (Question 18)

Common Element B, Spares Accuracy

The questions grouped under B have specific reference to spares accuracy.

Questions related to B:

- Is the maintenance master data regularly reviewed? (Question 9)
- Are materials and spares available in advance for work already planned? (Question 10)
- Are the spares used for planned maintenance fit for service? (Question 12)
- Is there evidence of satellite stores? (Question 13)
- Are all spare parts adequately identified? (Question 14)

Common Element C, Scheduled Maintenance Replacements

The questions grouped under C have specific reference to scheduled maintenance replacements.

Questions related to C:

- Are there schedules in place to identify deterioration of equipment? (Question 3)
- Is there commitment from management to improve equipment reliability? (Question 4)
- Is there a long term strategic equipment replacement plan? (Question 15)

Common Element D, Visual Performance Measurements

The questions grouped under D have specific reference to visual performance measurements.

Questions related to D:

- Is the cost of equipment downtime visually displayed to all parties involved? (Question 16)
- Are downtime history trended? (Question 17)
- Are there visual indicators for product quality? (Question 19)
- Are there visual indicators for plant availability? (Question 20)
- Are there visual indicators for plant throughput? (Question 21)
- Are there visual measurements for engineering personnel effectiveness? (Question 22)

Common Element E, Technical Training and Development

The questions grouped under E have specific reference to technical training and development.

Questions related to E:

- Are operators and engineering personnel trained with the necessary equipment and technical knowledge? (Question 1)
- Are there departmental training barriers? (Question 5)
- Is the investment in the training of people a focus area in your department? (Question 7)
- Is there a structured training programme in place for engineering personnel? (Question 8)
- Is there a career path designed per individual to promote personal growth? (Question 23)
- Is there a personnel retention strategy in place? (Question 24)
- Is there a succession planning strategy in place? (Question 25)

3.6.2 Questionnaire

TABLE 3 - Questionnaire and response per question

	Question	Yes	No	N/A	Commonality indicators
1	Are operators and engineering personnel trained with the necessary equipment and technical knowledge?	8	22	0	E
2	Are repetitive equipment failures investigated?	10	20	0	A
3	Are there schedules in place to identify deterioration of equipment?	7	23	0	C
4	Is there commitment from management to improve equipment reliability?	9	21	0	C
5	Are there departmental training barriers?	12	15	3	E
6	Is root cause analysis being done to fix the problems and not only the symptoms?	17	13	0	A
7	Is the investment in the training of people a focus area in your department?	3	27	0	E
8	Is there a structured training programme in place for engineering personnel?	24	6	0	E
9	Is the maintenance master data regularly reviewed?	15	15	0	C
10	Are materials and spares available in advance for work already planned?	9	21	0	B
11	Are equipment repaired within planned time?	2	28	0	A
12	Are the spares used for planned maintenance fit for service?	4	26	0	B
13	Is there evidence of satellite stores?	5	25	0	B
14	Are all spare parts adequately identified?	7	23	0	B
15	Is there a long term strategic equipment replacement plan?	9	21	0	C
16	Is the cost of equipment downtime visually displayed to all parties involved?	4	26	0	D
17	Are downtime history trended?	16	14	0	D
18	Are drawings and specification up to date for critical equipment?	2	28	0	A
19	Are there visual indicators for product quality?	10	20	0	D
20	Are there visual indicators for plant availability?	10	20	0	D
21	Are there visual indicators for plant throughput?	10	20	0	D
22	Are there visual measurements for engineering personnel effectiveness?	7	23	0	D
23	Is there a career path designed per individual to promote personal growth?	0	30	0	E
24	Is there a personnel retention strategy in place?	2	28	0	E
25	Is there a succession planning strategy in place?	4	26	0	E

3.7 Data analysis of Questionnaire

The following organizational groups were interviewed and graphically display the knowledge base distribution and business focus of information gathered.

3.7.1 Organizational Groups

FIGURE 18 - Production Team

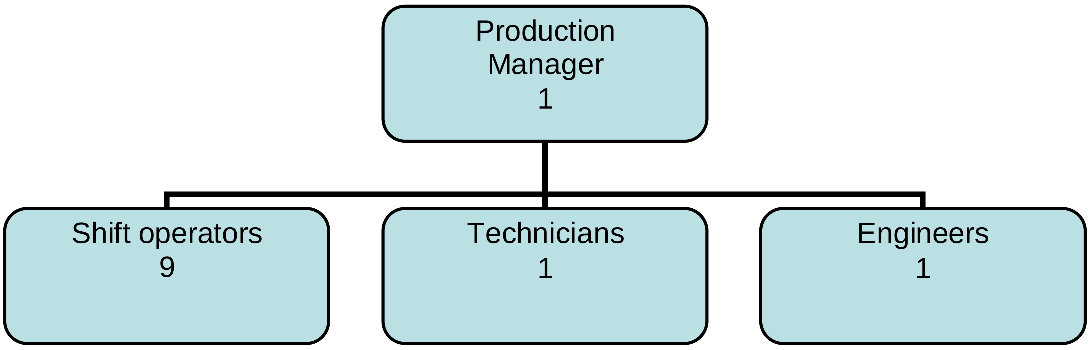


FIGURE 19 - Engineering Team

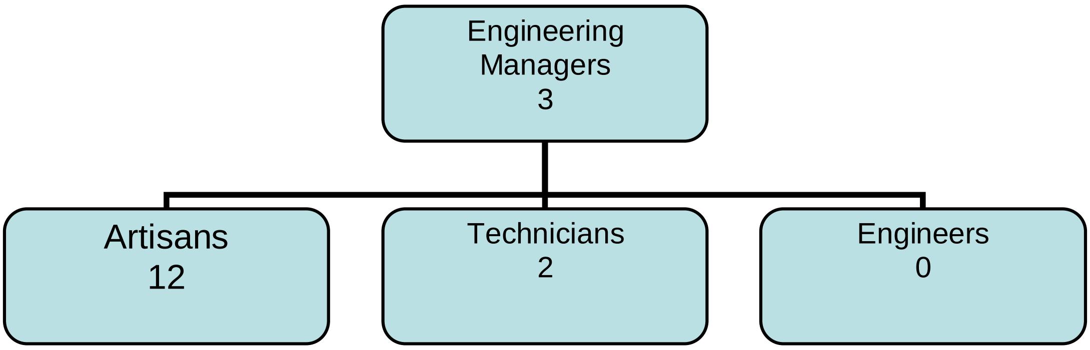
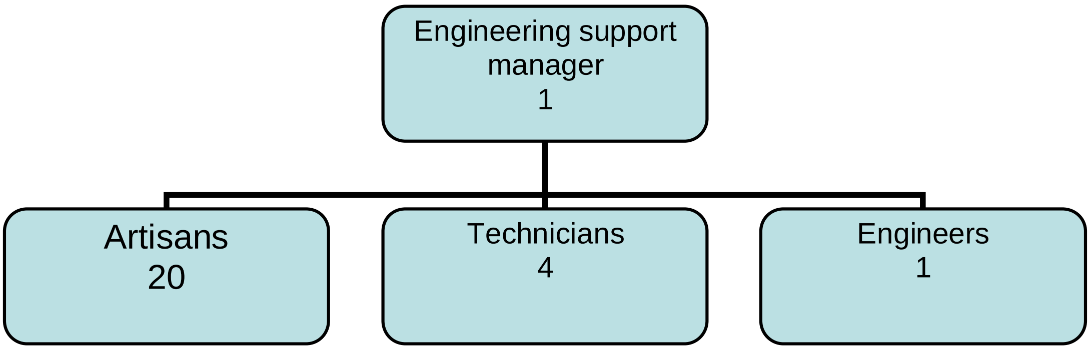


FIGURE 20 - Engineering Support Team (Turbo Services)



The employee tenure ranges from newly employed over 20 years experience. The maximum total of participants to the questionnaires is 55 as this is the total compliment of people as shown in the organograms (Figure 18, 19 and 20). Fifty (50) questionnaires were distributed and 30 unspoiled and workable copies were returned for analysis. The minimum amount of workable returned questionnaires to make statistics reliable is 80% with a margin of error at 5% is 29 (http://www.danielsoper.com, Accessed 27 May 2009). Thirty (30) returned questionnaire copies were used.

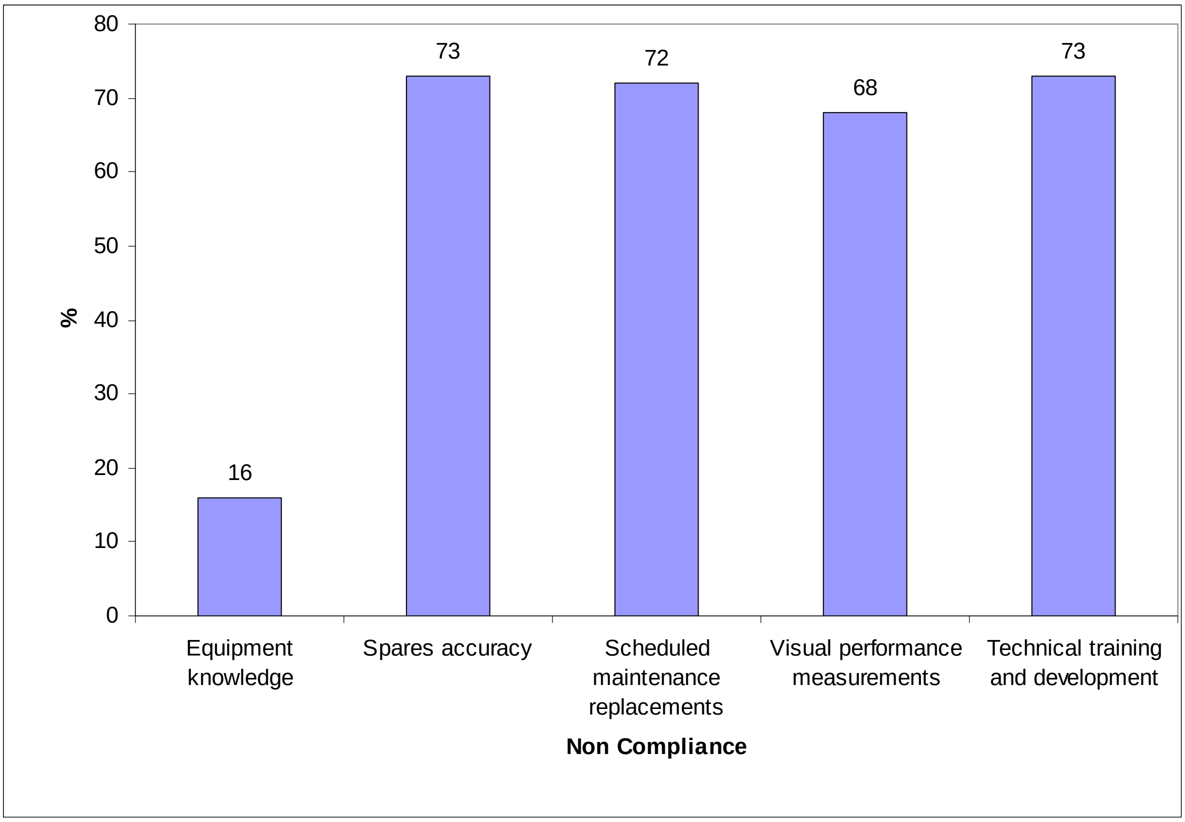
The Results are tabled below:

TABLE 4 - Summary of Response to Questionnaires

Tools	Maximum compliance/ Total number of response	Actual non-compliance	Percentage Non - compliance
Equipment knowledge A	120	19	16%
Spares accuracy B	150	110	**73%**
Scheduled maintenance replacements C	90	65	**72%**
Visual performance measurements D	180	123	68%
Technical training and development E	210	154	**73%**

In Table 4 the maximum compliance is the maximum number of response from the questionnaires that can indicate that this element is adequately addressed. As example element A, equipment knowledge, has four related questions and there were 30 questionnaires. The total number of response to this element is 4 * 30 and is 120 responses. From the 120 possible responses a total of 19 (16%) indicated that this element is not adequately addressed. The actual non-compliance number is a summary of the questionnaires that suggest that this element is not adequately addressed.

GRAPH 1 - Graphical representation of questionnaire response



This graph can be interpreted that the workforce has adequate knowledge of the existing equipment. There is in need for spares accuracy and a visual representation of plant performance. The need for technical training and scheduled maintenance replacement strategies is enforced. This graph corresponds with the results obtained from the interviews with plant personnel that also indicated the need to replace old and unreliable equipment and they then want training on these equipment.

The interviews and the questionnaire response indicate the need for technical training and development. A statistical correlation must be done to determine if there is a correlation between technical training and development and any of the other asset management elements using the questionnaire response data. Therefore the correlation between E and A, B, C and D must be calculated. The common element E, technical training and development, will be used as the base of the correlation calculation.

3.7.2 Correlation

(i) The correlation between Technical training and development (E) and Equipment Knowledge (A) is:

E and A					
Number of pares of response (N)	**Sum of product of paired scores Σea**	**Sum of E scores Σe**	**Sum of A scores Σa**	**Sum of squared E scores Σe^2**	**Sum of Squared A scores Σa^2**
30	**98**	**154**	**19**	**840**	**33**

r = Correlation

$$r = \frac{N\Sigma ea - (\Sigma e)(\Sigma a)}{\sqrt{((N\Sigma e^2 - (\Sigma e)^2)) * ((N\Sigma a^2 - (\Sigma a)^2))}}$$

This method is known as the Spearman correlation coefficient and the result will always be between -1.0 and + 1.0. For a negative correlation between two items compared, the result of this calculation will be negative. For a positive relationship the result will be positive. Technical training and development was use as the base for the correlation calculation as this element has a high value of non-compliance as indicated in the questionnaire response, Table 3.

Result for correlation between E and A is +0.01

Therefore there is a **very low positive correlation** between technical training and development and equipment knowledge.

(ii) The correlation between Technical training and development (E) and Spares accuracy (B) is:

E and B					
Number of pares of response (N)	**Sum of product of paired scores Σea**	**Sum of E scores Σe**	**Sum of A scores Σa**	**Sum of squared E scores Σe^2**	**Sum of Squared A scores Σa^2**
30	**590**	**154**	**110**	**840**	**429**

Result for correlation between E and B is +0.72

Therefore there is a **strong positive correlation** between technical training and development and spares accuracy.

(iii) The correlation between Technical training and development (E) and Scheduled maintenance replacements (C) is:

E and C					
Number of pares of response (N)	**Sum of product of paired scores Σea**	**Sum of E scores Σe**	**Sum of A scores Σa**	**Sum of squared E scores Σe^2**	**Sum of Squared A scores Σa^2**
30	**347**	**154**	**65**	**840**	**166**

Result for correlation between E and C is +0.38

Therefore there is a **positive correlation** between technical training and development and the effect of scheduled maintenance replacements.

(iv) The correlation between Technical training and development (E) and visual performance measurements (D) is:

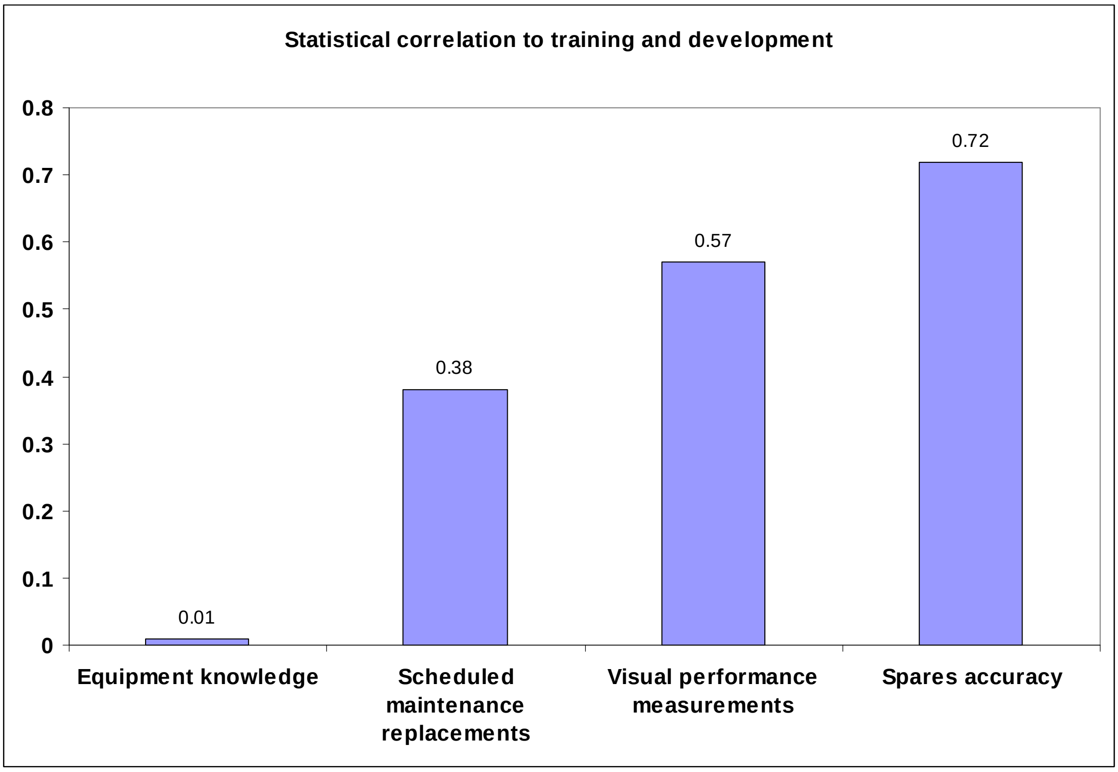
E and D

Number of pares of response (N)	Sum of product of paired scores Σea	Sum of E scores Σe	Sum of A scores Σa	Sum of squared E scores Σe^2	Sum of Squared A scores Σa^2
30	**656**	**154**	**65**	**840**	**542**

Result for correlation between E and D is +0.57

The **positive correlation** is between technical training and development and visual performance measurements. There is a positive correlation between all five commonalities of asset management.

GRAPH 2 - Statistical correlation to training and development



The highest value of correlation to technical training and development is spares accuracy. The questions related to spares accuracy refer to master maintenance schedule reviews and the availability of spares that are fit for use.

3.8 Chapter Summary (Narrative of this Dissertation)

Data was gathered from interviews and questionnaires. The minimum sample needed for an 80% confidence and a 5% margin of error was 29 people. The data from the questionnaire response used was from 30 people. The data used can therefore be treated as valid and 80% reliable (http://www.danielsoper.com, Accessed 27 May 2009).

The interviews indicated that there is a need to do scheduled maintenance replacements. The people that operate and maintain equipment in this production facility need technical training and development on the equipment in use. An investment in the technical training and development of the engineering and production departments will be experienced by the personnel as a commitment from management to invest in the competence of the workforce. The questionnaire response confirmed the need for scheduled maintenance replacements. There is a positive correlation between the five commonalities of asset management. The highest correlation was between technical training and development and the spares accuracy.

The questions related to these two elements related to the availability of spares that are fit for use and investment in technical training and development programmes for employees.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

The aim of this research was to identify tools to increase the plant reliability and asset performance by using asset management principles. These tools must be applied to increase the proactive work capacity index of the engineering department.

This research can be used by the Prillan engineering and plant managers as a guide to measure and improve productivity and plant integrity. The suggestions made can be implemented immediately at the explosives plant in Sasolburg. Literature review on asset management models indicated the following similarities between the models researched:

- Equipment knowledge
- Spares accuracy
- Scheduled maintenance replacements
- Visual performance measurements
- Training and development

4.1.1 From the interviews and questionnaires it was found that the engineering and operational teams have a limited knowledge of asset management principles and the application of an asset management model.

4.1.2 From the case study audit it is noted that the master data of equipment was not updated and is incorrect. This result in equipment not returned for production within planned time after maintenance activities are performed. Wrong and outdated technical specifications are used to procure material and spares.

4.1.3 From spares accuracy and plant integrity audit reports it is evident that the computerized maintenance management system in use, SAP R/3, is not fully utilized to use the data available on this system to predict failures and the proactive work capacity index.

4.1.4 There is no evidence of career paths, succession planning and retention strategies. There is a need to develop balanced scorecards to align the individual and business strategies. The need for technical training and development is rated as the highest need and can be interpreted that they need more quality and less generic training. They feel that they can make a better contribution towards the business success and need more stretched targets.

4.1.5 Limited key performance measures for plant and equipment performance are in place and therefore the plant performance cannot be properly measured and managed.

4.1.6 Not all employees understand their performance targets as some targets and objectives are not specific, measurable or attainable [60]. Methods to measure the efficiency of the engineering planning and execution activities are not identified. Roles and responsibilities are not clearly defined.

4.1.7 There is unhappiness within the engineering and production workforce of the Prillan plant.

4.1.8 The correlation between the need for technical training and development and the spares accuracy indicates the need for equipment specific training.

4.2 Recommendations

4.2.1 The overall equipment efficiency (OEE) must be measured and employees must be trained on the possible six losses and the influence of all activities on this measurement. The overall equipment efficiency must be measured daily and must include:

Quality:	Actual output vs. good output to indicate scrap and rework
Plant performance:	Target output vs. actual output to indicate reduced production speed and stoppages
Availability:	Operating time vs. actual running time to indicate production schedule accuracy and failures

4.2.2 Frequent work execution reviews must be implemented. This creates the opportunity to review and eliminate future breakdowns and to update the master data used to determine standard time and required spares for engineering activities. The updating of the master data will reduce the need for satellite stores as spares used will be fit for service. These reviews can be used as a tool to monitor the deterioration of equipment and to do accurate planning and scheduling.

4.2.3 SAP training of the planners and the management of this plant will ensure that functionalities such as user status are used and understood.

4.2.4 It is recommended that the engineering and operational teams of the Prillan explosives manufacturing plant be trained on the meaning and application of asset management principles. This training must include planned maintenance requirements. Competence profiles must be developed per engineering discipline and used to establish specific and individual training and development needs. These training and development needs must be formulated in a matrix and must be included in the balanced scorecards of the individuals. The knowledge gained from this technical training and development plan must be used to update technical drawing, procedures and equipment specification in the master data.

4.2.5 It is recommended that the visual performance indicators of the engineering team already in use be trended weekly and that action plans with objectives and targets must be implemented to ensure continuous improvement. The existing indicators include % emergency work, % urgent work, % scheduled tasks completed, capacity planning and the backlog status. The mean time between failures (MTBF) measurement of critical pumps is an existing measurement.

4.2.6 The management of this plant must eliminate dissatisfaction of employees by ensuring that salaries, working conditions and other job context factors are reasonable and appropriate. There is a need for the development of career paths for all employees. The management of this plant must enhance employee motivation by providing opportunities for growth, achievement and responsibility.

4.2.7 The use of the user status on the work orders will have the benefit of financial control and the effective management of service providers. The updating of the user status requires discipline and this must be enforced by the plant management.

4.2.8 A change management model must be implemented and this model must be logical and properly planned. The model used must include a clear description of the reason for change, the desired outcome and an action plan.

4.2.9 DILO’s on all the engineering functions must be done regularly. This must be used as a tool to eliminate unproductive time and to increase wrench time and the proactive work capacity index. It is also a tool to identify duplication of activities and to optimize the engineering organizational structure.

Action plan

The following action plan is recommended:

	Action	Responsible	Implimentation Period
1	Design a change management model	Manangers	1 Month
2	Training on Asset Management Principles	Managers/Human resources	2 Months
3	Design visual representation of performance (Dashboard)	All	3 Months
	OEE and six losses		
	Wrench Time		
	% Urgent work orders		
	% Emergency work orders		
	PM Schedule compliance		
	Capacity planning		
	Backlog		
	User status information		
	Departmental training compliance		
4	Implement weekly work reviews	Planners/Managers	Immediately
5	Implement weekly overdue open orders review	Planners/Managers	Immediately
6	Update master data	Engineers/Technicians/ Planners	2 Years
7	Develop a training matrix and competence profiles	Managers	3 Months
8	Develop balanced scorecards	Managers	1 Month
9	Do 6 monthly DILO's	Planners	6 Months
10	Review maintenance strategies	Engineers/Technicians/ Planners	1 Year
11	Analyze failure data and determine equipment replacement strategies	Engineers/Technicians/ Planners/management	6 Months

4.3 Verification of recommendations

The recommendations of this research were tested with the current engineering manager, Prillan, Sasol Nitro (Interview with T. Böhlander, 12 August 2009). The reason for this verification interview of recommendations was to determine if the results of this research is a true reflection to the opinion of the engineering manager. This interview was used to determine if any of these recommendations were implemented during the time of this research and what effect it had on the proactive work capacity and equipment reliability and performance.

4.3.1 The measurement of overall equipment efficiency (OEE):

This measurement can be used to increase the proactive work capacity index and plant reliability and performance. This will only be done if individuals can associate themselves with problems identified that influence the six possible losses and are willing to eliminate the problems identified. There are no documented objectives and targets for people for actions needed on influences on the overall equipment efficiency of this manufacturing plant. The interviewee stated that the plant throughput is at times reduced to eliminate stop-starts of this plant.

4.3.2 Weekly work execution reviews:

Reviews of engineering activities are conducted and these sessions can be used more productively to identify issues that must be focussed on.

4.3.3 SAP training:

The planning department was trained in the use of SAP and the value of data within this system that can be used to measure the engineering team efficiency. The training of other engineering personnel with the use and recovery of data within SAP will add value to the engineering efficiency. This training will reduce time spend by managers to gather and display data on the losses that influence the OEE and the proactive work capacity index of that plant.

4.3.4 Technical training and development:

There are no documented competence profiles for the engineering team and succession planning is not officially identified. It is the opinion of the engineering manager that artisans must be competent to perform engineering activities if they are qualified in a trade.

4.3.5 Existing visual performance measures:

The interviewee stated that the existing performance measures indicate an improvement over the time that these measures are in use. This increase in performance is the result of better production online planning. There is however a need to do better plant planning by the logistics department. He stated that he does not agree with the magnitude of the problem stated with regards to the accuracy of spares and the master data. He indicated that there is a need to increase the reliability of the support function that purchase and manage inventory. In his view the problems are:

- Spares are delivered at the wrong locations
- Lack of technical knowledge in the purchasing and supply management department
- The inventory database is not updated

4.3.6 Dissatisfaction of employees:

The manager interviewed has the opinion that in any organization there will be people that are not happy for some reasons. He mentioned the need for participation of all employees to work towards the business strategy. The motivation of employees to achieve the departmental and business strategy is lacking. No change model is in place and must be developed with the cooperation of all individuals involved. He stated that there is a need to design and implement a change management program.

4.3.7 User status

It is the view of the interviewee that user status measurement is a function of the financial department. This has specific reference to late or no invoicing and financial management.

4.4 Validation of results

This research was not validated due it not being a requirement and some of the tools presented in this research are in the process of implementation. For this reason there are no results available.

4.5 Research value

The influence of change management to a new strategy is highlighted to the plant manager. This also reveals to the manager the importance to revise strategies and that the measurement of services rendered is important. A holistic view towards a maintenance strategy must be followed to include accurate inventory and master data, and up to date acceptable maintenance strategies to ensure a profitable, safe and reliable manufacturing plant. The planning, execution and review sequence of maintenance activities are explained and measurements of plant and personnel performance are proposed, such as the use of user status per task. This research provides a guideline to engineering and plant managers on how to develop a maintenance strategy and methods and tools that can be used to evaluate and continuously measure the effectiveness of the implementation of such a strategy.

4.6 Achievements and Shortcomings

A larger group could have been interviewed to obtain raw data. This is a shortcoming and can be improved on if the student networks with more managers and maintenance personnel operating similar plants in the world. For this research a questionnaire was developed to obtain more raw data. Room for improvement and other opportunities for this research study include the analysis of current equipment reliability and history. Equipment age analysis could be done to confirm interview responses. The influence of existing personnel training and development programs and competence on the plant performance and safety statistics would have added value. This research achieved the objective to identify tools that can be used to manage and trend equipment and engineering performance. This can be used as a dashboard to track and trend the performance of the explosives manufacturing plant to entrench an asset management culture.

4.7 Future Research

Future research suggestions:

(A) Methods to close the gap between the projected proactive work capacity index as indicated in Figure 2.

(B) The design and application of balanced scorecards to ensure alignment of all departments with business strategy.

(C) First line maintenance performed by operations personnel, the effect and training needed.

APPENDIX A - REFERENCES

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APPENDIX B – ABBREVIATIONS, ACRONYMS AND DEFINITIONS

TERM	DESCRIPTION
CMMS	Computerized Maintenance Management System
DILO	Day in the life of
EAM	Enterprise Asset Management
FMEA	Failure Mode and Effect Analysis
JIT	Just In Time
OEE	Overall Equipment Efficiency
pH	Measure of the acidity or basicity of a solution
PPAN	Porous Prilled Ammonium Nitrate
PWCi	Proactive Work Capacity index
RACI	Responsible, Accountable, Consulted and Informed
RBI	Risk Based Inspections
RCFA	Root Cause Failure Analysis
RCM	Reliability Centered Maintenance
SAMI	Strategic Asset Management Inc
SAP-PM	SAP Plant Maintenance module
RAM	Reliability, Availability and Maintainability

KEYWORDS

Enterprise Asset Management
Balanced scorecard
Career paths
Equipment knowledge
Maintenance strategies
Master data
Overall Equipment Efficiency
Proactive work capacity index
Scheduled maintenance replacements
Spares accuracy
Training and development
User status
Visual performance measures

DEFINITION OF TERMS

Shareholder value

The value a shareholder is able to obtain from his/her investment in a company is referred to as Shareholder value. This is made up of capital gains, dividend payments, and proceeds from buyback programs and any other payouts that a firm might make to a shareholder (http://www.investwords.com, Accessed 15 February, 2006).

Motivation

Internal and external factors that stimulate desire and energy in people to be continually interested in and committed to a job, role, or subject, and to exert persistent effort in attaining a goal. Motivation is the energizer of behaviour and mother of all action. It results from the interactions among conscious and unconscious factors such as the intensity of desire or need, incentive or reward value of the goal, and expectations of the individual and of his or her significant others. The desire to do. Interest or drive (The Collins dictionary, 1986).

Organization

It is a number of people or groups having specific responsibilities and united for some purpose or work (The heritage illustrated dictionary of the English language, 1973).

Management

Management" (from Old French ménagement "the art of conducting, directing", from Latin manu agere "to lead by the hand") characterises the process of leading and directing all or part of an organization, often a business, through the deployment and manipulation of resources (human, financial, material, intellectual or intangible), (http://www.wikipedia.org, Accessed 20 March 2006).

Skill

Special ability in a task acquired by training (The Collins dictionary, 1986).

Planning

It is the process of setting goals, developing strategies, and outlining tasks and schedules to accomplish the goals (http://www.investwords.com, Accessed 15 February, 2006).

Asset

Any item of economic value owned by an individual or corporation, especially that which could be converted to cash. Examples are cash, securities, accounts receivable, inventory, office equipment, real estate, a car, and other property. On a balance sheet, assets are equal to the sum of liabilities, common stock, preferred stock, and retained earnings.

Anything of value or useful (The Collins dictionary, 1986).

Reliability Centered Maintenance (RCM)

A maintenance strategy designed to uncover the causes and consequences of breakdowns. RCM sets up priorities by the severity of the consequences. Preventative maintenance tasks and redesign are directed specifically at those failure modes that have the worst consequences. RCM is a procedure for uncovering and overcoming important failures (Levitt J, 2005:xxi).

Balanced scorecard

The balanced scorecard is a management philosophy, management system, and method of measuring compliance to objectives. It is a top-down method to translate an organization's mission and strategy into tangible linkages, interrelationships, specific activities and measures necessary for successful implementation (Mitchell J.S, 2002:80).

Overall equipment efficiency (OEE)

Overall equipment efficiency (OEE) is a normalized quantity representing net production yield made up of three percentages: availability, production rate and quality – all as a percentage of objective (Mitchell J.S, 2002:87)