DURBAN CAMPUS

A strategic plan for incorporating a maintenance strategy to support and sustain maximisation of product volumes

By

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CONFIDENTIALITY CLAUSE

04 September 2003

TO WHOM IT MAY CONCERN

RE: CONFIDENTIALITY CLAUSE

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

Sincerely

Bipath

096643

A. Bipath

DECLARATION

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

Signed……… Bipath ………………

Date… 04 SEPTEMBER 2003 …………………

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ABSTRACT

The Acerinox Group has recently acquired Columbus Stainless. With this acquisition, came a dramatic change in operations philosophy. This involves maximisation of product volumes and a low cost strategy throughout the plant. This paper serves to present the management dilemma currently present at Columbus Stainless: Is the current Corporate Maintenance Strategy able to support the manufacturing strategy as laid down by Acerinox? Is there a breakdown in synergy between this corporate maintenance strategy and plant-specific maintenance strategies and why? As part of the research methodology a construct has been developed to perform a gap analysis between World Class/Best Practice maintenance practices and the Columbus Stainless and plant-specific maintenance strategies. A gap analysis is also performed between the Columbus Stainless Maintenance Strategy and the plant-specific maintenance strategies at the Hot End of the organisation. A questionnaire is also used to determine the maturity level of the maintenance management in terms of World Class/Best Practice maintenance theory, the Corporate Maintenance Strategy and plant-specific maintenance strategies. This study has found that the Corporate Maintenance Strategy is able to support the maximisation of volumes and low cost strategy by comparing the World Class/Best Practice maintenance practices found in grounded theory, to the Corporate Strategy and to the plant-specific strategies. The results from this study also find that there is a breakdown in synergy between one plant at the Hot End of the organisation and the Corporate Maintenance Strategy. The reasons for the breakdown in synergy are identified and recommendations are made accordingly.

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1.1 Introduction

Columbus Stainless, situated in Mpumalanga Province is the only stainless steel producer in South Africa. The Acerinox Group, a Spanish consortium, has recently acquired Columbus Stainless. With this acquisition, came a dramatic change in operations philosophy. This involves maximisation of product volumes throughout the plant. This paper serves to present the management dilemma currently present at Columbus Stainless:

Is the current corporate maintenance strategy able to support the manufacturing strategy as laid down by Acerinox? What are the reasons for the breakdown in synergy between this corporate maintenance strategy and the plant-specific maintenance strategies and why?

The objectives of the study are based on the literature review, the problem statement and management dilemma, which involves conducting a study to check if the following is true:

The Columbus Stainless Corporate Maintenance Strategy (CSCMS) currently available is able to support and sustain the Columbus Stainless Manufacturing Plan.

There is a breakdown of synergy between CSCMS and plant specific maintenance strategies.

As part of the research methodology a construct (figure 1.2) was developed and Exhibit 6.1, Descriptors of Research Design (Cooper and Schindler 2001), was used as a basis for the research design. This study is a formal study that entails conducting a comprehensive theoretical study of common and "best practices" maintenance philosophies, and comparing them to those implemented by Columbus Stainless. Also, this formal study will include an investigation into whether the CSCMS will support the manufacturing plan, and thus sustain the maximisation of product volumes and low cost strategy envisaged.

1.2 Background

Columbus Stainless expansion was commissioned in 1995. It truly transformed Columbus Stainless into an integrated large-scale operation with the potential to be the world's lowest cost stainless steel producer. Since then, Columbus Stainless has undergone substantial change, including downsizing, restructuring and the introduction of modern management philosophy. The latest focus includes outsourcing of system house (Information Technology Department) and non-core human resources activities. Organisational capacity has improved through focused recruitment and training. Training, Safety and Quality Systems have also been improved on.

In January 2002, Columbus Stainless became part of the Acerinox group. As a result, it became part of a world leading Stainless Steel producer and consequently enjoys access to their worldwide distribution network. In order to direct the organisation and to ensure focus, a mission and vision statement was developed. The mission of Columbus Stainless is "Adding stainless steel quality to life". The vision statement is "Becoming the best operation in the Acerinox Group".

In the case of Columbus Stainless, the focus remains to ensure robustness of the business through high volume, low cost producer strategy at the hot end of the business. According to the *Columbus Stainless Five-Year Business Plan* (2002) maximising production volume will be attained by:

- Increasing the volume at the hot end of the business by increasing slab output and ensuring Steckel headroom capacity to work it away;
- Increasing the volume at the hot end of the business by improving asset utilisation of existing equipment mainly through de-bottlenecking projects.
- Increasing the volume of value-added and the extent of value adding at the cold end of the business through high utilisation of existing equipment, a prudent capital investment program and innovative application of technology;
- Increasing Columbus Stainless effective margin earned on especially local markets sales by erecting a service (distribution) centre;

- Minimising cost across the supply chain with the use of advanced planning systems that support improvement in productivity and efficiency.

Figure 1.1 was adapted fro Columbus Stainless's Five Year Business Plan and depicts the situation that needs to be achieved before April 2005 and then maintained until the end of the business planning cycle.

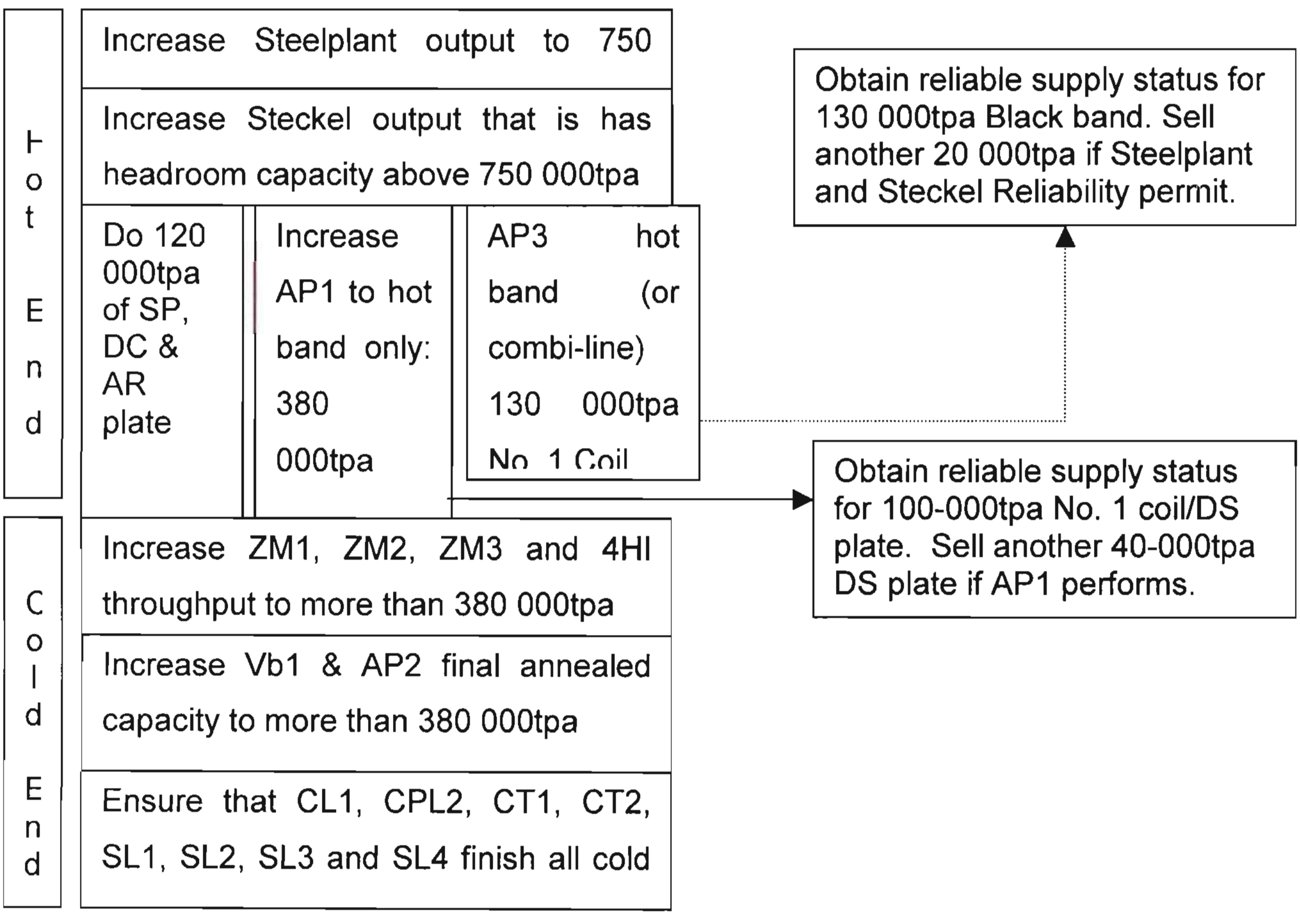


Figure 1.1: Production Objectives for Columbus Stainless as per Five Year Business Plan, May 2002

1.3 Motivation for the Study

With the recent acquisition by the Acerinox Group, there is an increasing demand to demonstrate a return on investment. There is increasing pressure to achieve high plant availability, improved plant performance and to contain costs. The profitability of Columbus Stainless is dependent on the maintenance function complying with its budget. An overrun on the cost budget can impact heavily on the bottom line of the business while, under spending the maintenance budget can impact negatively on the long-term reliability and condition of the assets. In order to sustain its business, Columbus Stainless should also generate sufficient reserves to enable it to further invest in the development of its production processes, services and people. The company's shareholders are expecting a return on both their initial investment and capital growth, which is a function of the company's longer-term development and growth prospects.

In terms of customer satisfaction, both internal and external, maintenance serves to improve the quality of the product or service supplied to customers. Also, operations will not be able to supply the product or service to customer if the equipment is not sufficiently available and if the equipment cannot operate at the required rate of output. Maintenance contributes to the reputation of Columbus Stainless by way of compliance with safety, health and environmental regulations, and conditions of equipment, tools, workshops and other facilities.

In order to achieve the above, synergy has to be achieved between the corporate maintenance strategy, and the plant-specific maintenance strategies.

1.4 Value of the study

The benefits that can result from this study are:

- This study can form the basis for comparison of maintenance philosophies adopted by World Class/Best Practice maintenance theories and those philosophies adopted by Columbus Stainless.
- The outcomes of this study can give a good indication on the effectiveness of the corporate maintenance plan and the plant-specific maintenance plans.
- All the constraints within the maintenance strategies can be identified, and recommendations fro improvements can be made accordingly.

1.5 Problem Statement and Management Dilemma

Currently there exists an organisational Columbus-wide Corporate Maintenance Strategy available. However, this plan and the various plant-specific maintenance plans are very much misaligned. With the acquisition of Columbus Stainless by Acerinox, the operations philosophy has changed dramatically, with the maximisation/increase of product volumes. Acerinox has, together with Columbus Stainless, embarked upon a new manufacturing strategy. The basis of this plan involves increased throughput, and low cost production. Columbus Stainless has identified that maintenance is one of the key drivers for Overall Equipment Effectiveness (OEE) improvements, overall yield, becoming a cost leader, and increasing processing speed and volume. Consequently, a focused initiative has been driven to ensure that maintenance systems are in line with worlds best. This initiative has been completed and the emphasis is now to ensure that personnel utilise the system. According to the *Columbus Stainless Five-Year Business Plan* (2002):

The basics involve Disciplined planning, master schedule management and job cards

Management;

- Quality of information on deviations and job cards;
- Analysis of equipment breakdowns;
- Team members doing what is required of them in their roles;
- Spares stockholding as sub-assemblies for critical/high risk equipment in order to reduce downtime due to breakdowns.

Management Dilemma

Is the current corporate maintenance strategy able to support the manufacturing strategies as laid down by Acerinox in the manufacturing plan? Currently there is no synergy between CSCMS and the plant-specific strategies. Thus there is no shared learning and integration. What causes the breakdown of this synergy and why?

1.6 Objectives of this Study

The primary objective of this research is to investigate whether the CSCMS that is currently available is able to support the Columbus Stainless Manufacturing Plan, and hence be able to sustain the maximisation of volumes and low cost leadership strategy. Secondly, to establish if there is a breakdown in synergy between the CSCMS and the plant-specific maintenance plans at the hot end of the organisation, and the reasons.

1.7 Research Methodology

The research methodology is base on the construct developed (see figure 1.2) from the problem statement, and the objectives of this study.

This research consists of a formal study. This entails conducting a comprehensive theoretical study of common and World Class/Best Practice maintenance philosophies, and comparing them to those implemented by Columbus Stainless. Also, this formal study includes an investigation into whether the CSCMS will support the manufacturing plan, and thus sustain the maximisation of product volumes and low cost strategy envisaged. A self-administered Maintenance Management Questionnaire is also used to assess at what level of maintenance management or maintenance excellence, according to grounded theory, each plant and the overall Hot End of the business is at currently.

Selection and size of sample

The sampling frame included a list of the personnel at two plants at the Hot End of the organisation. A stratified random sampling technique is used. The reason for selecting the Hot End of the organisation is because operational stability, also in terms of tempo and rhythm, is a prerequisite for volume optimisation and value adding at the cold end of the business as well. It is of utmost importance to focus on all processes and actions necessary to ensure optimal machine functionality at the hot end – functionality includes reliability, availability, accuracy of operation, and safety. Although this is critical throughout the organisation, if the target product volumes are not maximised at the hot end, then an increase in volumes at the cold end of the business will also not be realised.

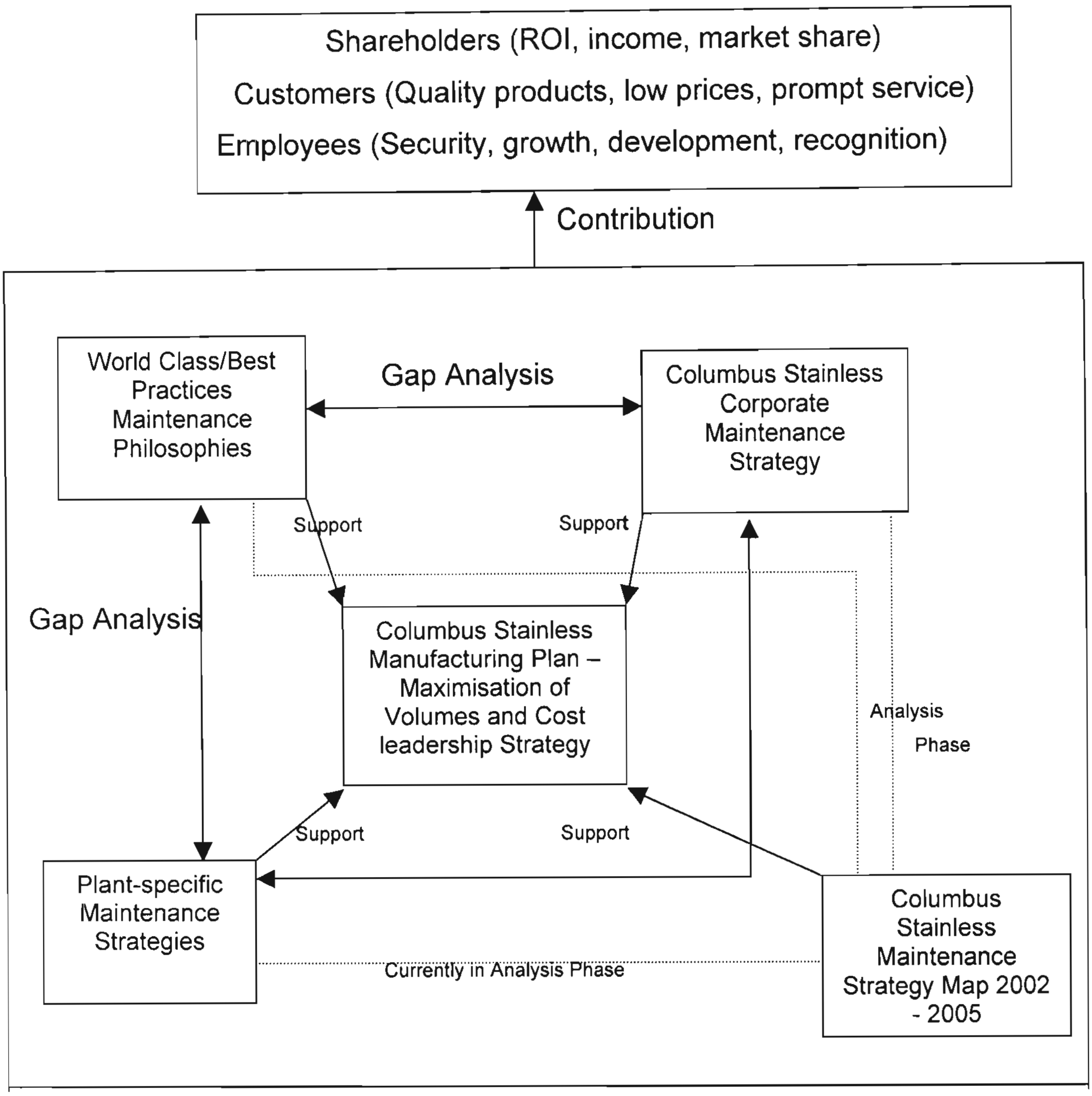


Figure 1.2: Construct Developed to Perform this Study

Method of Data Collection

An interrogation/communication method of data collection is employed. Secondary data on maintenance strategies selected, are critiqued using grounded theory as reference. Collected data also includes primary data that results from a self-administered questionnaire. The questionnaire was e-mailed to majority of the respondents, and hand delivered to those that do not have e-mail. The questionnaire was designed to include interval data, which allowed descriptive statistics to be performed by means of software packages, like Microsoft Excel.

With employment of an ex post facto design, the researcher will have minimal manipulation of any variables, thus reducing the introduction of bias. The first part of the study is a descriptive study. The theory will entail discussions of various maintenance philosophies and compared to the CSCMS and plant-specific maintenance plans to find out specific relationships. The second part of this study is a causal study. Here an evaluation is done to determine if there is a breakdown in synergy between the CSCMS and plant-specific maintenance plans, and the reasons for this. Cross-sectional studies are carried out because of the limited time available for conducting this study.

1.8 Limitations and Constraints of the study

The following limitations have been included in this study:

- The time available to conduct this study.
- The secondary data available might not be accurate.
- The information that the researcher receives from the various people is accurate and honest, without bias.

1.9 Structure of the study

Chapter two provides a brief introduction of how maintenance evolved and developed over time, and provides grounded theory of World Class/Best Practice maintenance practices.

Chapter three presents the latest available Columbus Stainless Corporate Maintenance Strategy. The plant-specific maintenance strategies of the Hotmill (one of the plants at the hot end of the organisation) are also presented.

Chapter four evaluates the maintenance strategies described in chapter 3 against the grounded theory presented in chapter 2. The Corporate and Plant-specific Maintenance Strategies are evaluated to see if they support World Class/Best Practice maintenance strategies. The plant-specific maintenance strategies are also evaluated to see if they support the Corporate Maintenance Strategy. Gap analyses resulting for each of the above evaluations are then presented. This chapter also discusses the results obtained from the maintenance management questionnaire.

Chapter five concludes the study by presenting the conclusions developed from the evaluations and results of the questionnaire. The recommendations on improvements to be made are also presented here.

1.10 Chapter Summary

This research consists of a formal study. This entails conducting a comprehensive theoretical study of common and World Class/Best Practice maintenance philosophies, and comparing them to those implemented by Columbus Stainless. Also, this formal study includes an investigation into whether the CSCMS will support the manufacturing plan, and thus sustain the maximisation of product volumes and low cost strategy envisaged. A self-administered Maintenance Management Questionnaire is also used to assess at what level of maintenance management or maintenance excellence, according to grounded theory, each plant and the overall Hot End of the business is at currently.

Chapter Two: maintenance Philosophies

2.1 Introduction

Although no operation should be indifferent to failure, in some operations it is vital that products and services do not fail – aeroplanes in flight or electricity supplies in hospitals, for example. In some situations, dependability on other products and services, such as car seat belts, the police service, and other emergency services, is not just desirable, it is essential. Having dependable products and services is also a way for organisations can gain competitive advantage.

Maintenance is the term used to cover the way in which organisations try to avoid failure by taking care of their physical facilities (plant, equipment and buildings). It is an important part of most operation's activities, especially those, like Columbus Stainless, whose facilities play a central role in creating their goods and services.

According to Pycraft et al. (2000) organisations, who are almost always concerned with improving the dependability of their operations and the products and services which they produce, try to have strategies in place which attempt to minimise the likelihood of failure and learn from failure when it does occur. They also need to recognise, however, that failures will occur, in spite of all attempts to prevent them. What is then important is that they have plans in place, which help them recover from the failures when they do occur.

This chapter puts forward the grounded theory regarding the various components of failures and maintenance. This will include various discussions on, but not limited to:

- Failure detection and analysis.
- Improving the operation's reliability.
- Failure recovery.
- Approaches to maintenance.
- Maintenance philosophies and concepts.

- Continuous improvement.

2.2 Why various operations fail

Failure problems and mistakes are an inevitable and intrinsic part of operations, and there are several reasons for these failures occurring. According to Pycraft et al. (2000) machines can break down, customers might make unexpected demands which the operation fails to meet, staff may make simple errors in their jobs which prevent normal working, materials from suppliers could be faulty, and so on. Hence, failures can be classified into:

- Those which are caused by faults in the material or information inputs to the operation – supplier failures;
- Those which have their source inside the operation, because its overall design was faulty, or because its facilities (machines, equipment and buildings) or staff fail to operate as they should;
- Those that are caused by the actions of customers.

Failures caused by suppliers can be in the delivery or quality of goods and services into an operation, which can cause a failure within an operation. There could be a design failure because a characteristic of demand was overlooked or miscalculated, or a production line might have been installed in a factory, which in practice cannot cope with the demands placed on it, or because the circumstances under which the operation has to work are not as expected. Major facilities, that is, the machines, equipment, buildings and fittings, of an operation are liable to breakdown partially or cause a total and sudden cessation of operation. In other words, the "breakdown" could cause a machine to work below its normal rate, or it can bring a large part of an operation to a halt. Failures caused by people can be in the form of "errors", which are mistakes in judgement, or in the form of "violations", which are acts that are contrary to defined operating procedure. Customer failures can be as a result of customers' inattention, incompetence or lack of common sense or misuse of the products and services, which have been created by the operation.

Notwithstanding this categorisation of failure, Pycraft et al. (2000) mentions that the origin of all failures is some kind of human failure. A machine failure might have been caused by someone's poor design or maintenance, a delivery by someone's errors in managing the supply schedules, and a customer mistake by someone's failure to provide adequate instructions – the implications of this are, first, that failure can, to some extent, be controlled and, second, that organisations can learn from failure and modify their behaviour accordingly. This affords the "opportunity" to examine why failures occur, and to put in place strategies and procedures - management systems - like maintenance strategies, which eliminate or reduce the probability of them recurring.

2.3 What is maintenance?

In considering failures and the prevention, elimination or reduction thereof, and in considering all activities associated with maintenance, it is vital to have a clear understanding of what is meant by the word "Maintenance". In essence, maintenance means "a cause to continue" (Oxford dictionary) or "keep in an existing state" (Webster dictionary), or in plain English, "to make sure that equipment continues to do what its users want it to do". This implicates those actions and processes that must be aligned so as to cause equipment and other maintenance processes to continue with their intended functions for the rest of their expected and planned economic lifetime. This includes all processes and actions necessary to ensure optimal machine functionality, as per business requirements – functionality includes availability, reliability, accuracy of operation, and safety. In the context of an article by Willmott Consulting Services *Bridging the Gap between theory and practice in maintenance* that appeared in the JWP Journal (1992), maintenance is defined as being the management, control, execution, and quality of those activities which will ensure that optimum levels of availability and overall performance of plant are achieved, in order to meet business objectives. According to the article *Asset Management Processes and Tools* (Woodhouse 2001), maintenance strategies are the most fundamental engine of asset management. John Moubray (1997) also states that maintenance is also responding to changing expectations, which include a growing awareness of the extent to which equipment failure affects safety and the environment, a growing awareness of the connection between maintenance and product quality, and the increasing pressure to achieve high plant availability and to contain costs.

To ensure that optimal machine functionality is achieved, the maintenance processes, tools and actions necessary include amongst others, the following, many of which will be discussed further in this chapter:

- Asset Management
- Preventative maintenance (PM)
- Run to Breakdown (RTB)
- Condition-based maintenance (CBM)
- Reliability-centred maintenance (RCM)
- Breakdowns
- Total Productive maintenance (TPM)
- Failure prevention and recovery
- Total Quality Management (TQM)
- Failure detection and analysis
- Maintenance practices
- Costs
- Resources
- Lifecycle

Pycraft et al. (2000) demonstrates the following benefits of maintenance – why operations bother to care for their facilities in a systematic manner:

1. *Enhanced Safety*. Well maintained facilities are less likely to behave in an unprecedented or non-standard way, fail outright, all of which could pose a hazard to staff.

2. *Increased reliability*. This leads to less time lost while facilities are repaired, less disruption to the normal activities of the operation, less variation in output rates and more reliable service levels.
3. *Higher Quality*. Badly maintained equipment is more likely to perform below standard and cause quality errors.
4. *Lower Operating Costs*. Many pieces of process technology run more efficiently when regularly serviced: motor vehicles, for example.
5. *Longer Life Span*. Regular care, cleaning or lubrication can prolong the effective life of facilities by reducing the small problems in operation whose cumulative effect causes wear or deterioration.
6. *Higher End Value*. Well-maintained facilities are generally easier to dispose of into the second-hand market.

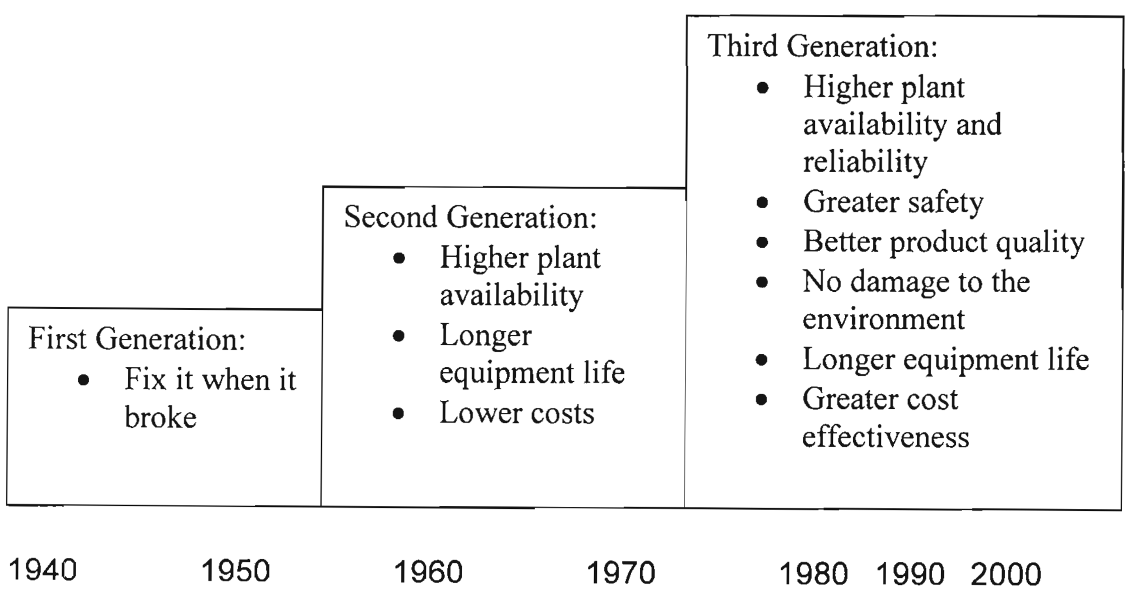
According to Thomlingson (internet 1) the objectives of a good maintenance function are, in addition to conducting those proactive activities to prevent failures from occurring, to:

- Support operations by keeping production equipment in good condition so that targets can be met.
- Maintain the plant facilities by keeping the plant site and its buildings, utilities, and grounds in a functional, attractive state.
- Conduct engineering projects like equipment modifications, construction, installation, and relocation.
- Develop a program to carry out its services.
- Organise itself to support the equipment maintenance need of production while conducting essential engineering projects.
- Execute its programs while utilising its resources productively.
- Perform quality work.
- Anticipate and prepare for future work.
- Achieve continued improvement by evaluating performance, taking corrective actions, and measuring progress.
- Prepare for future changes by anticipating needs and organising flexibly.

2.4 The evolution of maintenance

According to John Moubray (1997) over the past twenty years maintenance has changed, perhaps more so than any other management discipline. The changes are due to a huge increase in the number and variety of physical assets (plant, equipment, and buildings), which must be maintained throughout the world, much more complex designs, new maintenance techniques and changing views on maintenance organisation and responsibilities.

John Moubray, the author of Reliability-centred Maintenance, explains in great detail how maintenance has evolved over the past fifty years (1997). This can be summarised in figure 2.1. It is clear from this figure that since the 1930's, the evolution of maintenance can be traced through three generations.



<u>Figure 2.1: Growing expectations of maintenance (Adapted from John Moubray, 1997, p3)</u>

During the first generation (period up to World War II), industry was not very highly mechanised, so downtime did not matter, and as such, prevention of equipment failure was not a very high priority. Most of the equipment was simple and over-designed, which made it reliable and easy to repair. This did not warrant systematic maintenance of any sort beyond simple cleaning, servicing and lubrication routines.

With the second generation, wartime pressures (during World War II), the demand for goods of all kinds increased while the industrial manpower dropped sharply. This led to increased mechanisation, and the increasing dependence on complex and numerous types of machines grew. Downtime now became the focus, and this led to the idea that equipment failure could and should be prevented. The concept of preventative maintenance, which consisted mainly of equipment overhauls at fixed intervals, was developed. Moubray also mentions that during this generation, the costs of maintenance started to rise sharply relative to other operating costs. This led to the generation of maintenance planning and control systems, which helped to bring maintenance under control. Together with the amount of capital tied up in fixed assets and the sharp increase in the cost of this capital, people began to seek many ways in which they could maximise the life of the assets.

With the third generation, from the mid-seventies, the process of change became even more emphasised. Downtime was always a cause for concern, affecting the productive capability of physical assets by reducing output, increasing operating costs and interfering with customer service. These effects are being aggravated by worldwide moves toward just-in-time systems, where reduced stocks of work-in-progress mean that quite small breakdowns are now much more likely to stop an entire plant. New expectations regarding higher reliability and availability have now become key issues in the light of greater mechanisation and automation. This also means that more failures affect organisations ability to sustain satisfactory quality standards – applying as much to standards of service as it does to product quality.

With standards in areas of safety and environmental rising rapidly, increased failures have serious consequences in these areas. Organisations have to conform to society's safety and environmental expectations in certain areas, or they can cease to operate. This increases the dependence on physical assets, and also the costs to operate and own them. There is a demand to keep all assets working as efficiently for as long as organisations want them to, in order to achieve high levels of returns on investment. Another expectation is the rising cost of maintenance, in absolute terms and in proportion of total expenditure. Moubray states that this is now the second highest or even the highest element of operating costs in some industries, and has reached high priority levels for cost control.

The third generation has also seen a massive growth in new maintenance techniques, which include new developments such as:

- Decision support tools, such as hazard studies, failure modes and effects analyses and expert systems
- New maintenance techniques, such as condition monitoring
- Designing equipment with a much greater emphasis on reliability and maintainability
- A major shift in organisational thinking towards participation, team working and flexibility

In the light of the above a maintenance training workshop *Maintenance & Asset Management* (2003) also reveals that research has shown that organisations' maintenance management evolve through a number of phases as they develop towards "Physical Asset Management Excellence". These phases consist of the following levels 1 to 5:

- Level 1 – Little awareness of maintenance as a "management activity". The following takes place at this level:
  - Fire fighting ("if it breaks, fix it"). Mostly reactive to breakdowns.
  - There is total reliance on the individual attitudes of the maintenance crew. Roles and responsibilities are not clarified.
  - There is no TPM awareness.
  - No clear top-down commitment.
  - There is an unofficial objective to "respond quickly to request".

  - Maintenance costs are not available, and no performance reports generated.
  - Information systems are virtually non-existent with many manual systems.
  - PM consists only of shutdown inspections, with no failure records.
  - There is little or no planning and scheduling of maintenance work.
  - Weekend and other overtime accepted as the norm
  - Spares availability is low.

- Level 2 – Awareness of maintenance as a potential improvement area, still just an "engineering problem." The following activities takes place at this level:
  - PM plan in place, but not followed. Mainly reactive work pattern. Time based inspections are implemented, but collected data is not analysed.
  - Staff not suitably qualified.
  - Some planning of shutdowns and key overhauls.
  - Overtime worked to a regular pattern.
  - No maintenance budgeting and control in place.
  - Lack of support for proposals to improve maintenance. Continuous improvement consists of a one-time review of maintenance process.
  - No top-down or user involvement.
  - Operators given some maintenance responsibility.
  - There are some maintenance reports.
  - There is an unofficial objective to "support production".
  - Information system entails partial use of recognised maintenance software.
  - Stores are organised, but spares information is not accurate.
  - There are attempts at introducing a work order system. Some work is prioritised and inspection scheduling takes place

- Level 3 – Acceptance that reactive maintenance is wrong, with a commitment to improvement, with the following activities:
  - Routine maintenance is well established.

- There is a disciplined computerised work order system.
- A short-term plan is in place, with an official maintenance objective published.
- A fully trained staff and well-structured maintenance department.
- Some commitment to continuous improvement in maintenance.
- Machine efficiency is measured and downtime is defined by cause. More indicators, trends and other management reports are generated, with well-maintained history records.
- The information system id fully functional, but not linked to other systems.
- There are attempts to link the maintenance budget to a planned workload. Strict expenditure control exists.
- Spares are computerised with accurate information.
- Senior management occasionally discusses maintenance.

- Level 4 – Senior management commitment, continuous improvement, use of best practice techniques, reliable and accurate information. The following maintenance activities takes place at this level:
  - Senior management commitment is evident.
  - A comprehensive maintenance strategy guideline is available.
  - Predictive maintenance is preferred.
  - RCM is performed.
  - Continuous improvement is formal, cross-functional and participative.
  - Management performance and key performance indicators are defined, measured and regularly reported.
  - Maintenance budget and cost per equipment is based on history analysis, and is linked to the workload. Cost of non-conformance is monitored.
  - Maintenance is recognised as an important investment.
  - Information management is fully functional and linked to financial and materials systems.
  - Estimated times are used in planning and scheduling.
  - Some RCM, CBM, PM, FMEA techniques are used.

- Spares holding is regularly reviewed and linked to schedules.

- Level 5 – Best practice maintenance is established, with fully integrated information systems, users perform maintenance administration, and engineers use their skills for equipment performance improvement. At this level:
  - An integrated corporate maintenance strategy/asset strategy is in place.
  - Asset users are accountable for current asset performance.
  - Operators have appropriate maintenance skills; perform care and monitoring tasks – autonomous work teams, with maintenance staff concentrating on improving asset performance.
  - Well-qualified workforce (multi-skilled) in lean structure.
  - Equipment failures – not justified as run-to-failure – are rare.
  - There is a database and key performance indicators on equipment effectiveness; benchmarking and continuous improvement. Audit procedures are implemented regularly with reviews of process cost, time and quality.
  - A fully integrated information system with common database is an integral part of the maintenance management process. This incorporates an integrated maintenance and production planning system for planning and scheduling.
  - All maintenance tactics employed, such as PM, based on full value-risk program.
  - Asset management is discussed as an agenda item at board meetings, and spares holding are based on risk and cost analysis.
  - Advanced financial models used in decision-making.

Moubray (1997) summarises the challenges facing maintenance personnel as follows:

- To select the most appropriate techniques for their organisation.

- To deal with each type of failure process.
- In order to fulfil all the expectations of the owners of the assets, the users of the assets and of society as a whole.
- In the most cost-effective and enduring fashion.
- With the active support and co-operation of all people involved.

2.5 Approaches to Maintenance

Slack et al. (2000) states that, in practice an organisation's maintenance activities will consist of some combinations of three basic approaches to the care of its physical facilities. These are run to breakdown (RTB), preventative maintenance (PM), and condition-based maintenance (CBM). Many organisations adopt a mixture of these approaches because different elements of their facilities have different characteristics, and each approach to maintaining facilities is appropriate for different circumstances. The equipment lifecycle management is divided into these three approaches of maintenance. These three maintenance approaches or principles, have also been mixed and extended, and incorporated with various other principles or systems, to adopt various other maintenance methodologies, such as Reliability-centred Maintenance (RCM), and Total Productive Maintenance (TPM). These approaches will be discussed later in this chapter.

2.5.1 Run to Breakdown (RTB)

Run to breakdown – as the name implies – involves allowing facilities to continue to operate until they fail. Here no effort is made to anticipate or prevent failure modes to which it is applied, and so those failures are simply allowed to occur and maintenance work is performed only after failure has taken place. Failure in these circumstances is neither catastrophic nor so frequent as to make regular checking of the facilities appropriate. According to Slack et al. (2000) RTB is often used where the repair is relatively straightforward (so the consequence of failure is small), where regular maintenance is very costly (making PM expensive), or where failure is not at all predictable (so there is no advantage in PM because failure is just as likely to occur after repair as before).

2.5.2 Preventative Maintenance (PM)

Preventative maintenance involves attempts to eliminate or reduce the chances of failure by servicing – cleaning, lubricating, replacing and checking – the facilities at pre-planned intervals. According to Wilson (1999) this approach can result in a high degree of planned work, which can give an overall reduction in maintenance effort of up to 25% by reducing the volume of inefficient, reactive work. The available maintenance hours can then be either cut, or additional effort directed towards the continuous improvement of equipment and plant. Slack et al. (2000) mentions that PM is used where the cost of unplanned failure is high – because of disruption to normal operations – and where failure is not totally random (so the maintenance time can be scheduled before failure becomes very likely).

2.5.3 Condition-based Maintenance (CBM)

Condition-based maintenance attempts to perform maintenance only when the facilities require it. Here the need for corrective action or consequence-avoiding action is based on an assessment of the condition of the item, for example, continuously monitoring vibrations on a piece of equipment, which might indicate imminent bearing failure. Wilson (1999) indicates that the benefits arising from CBM result from the ability to prevent a failure occurring in situations where the indication of a problem is detected in sufficient time to do something about it. Cost saving will result from a number of areas, including:

- potential savings in maintenance labour from improved setting of work priorities;
- reduced consequential damage to plant by pre-empting failure;
- reductions in the costs arising from loss of plant availability; and
- improvement in personnel safety where failure would create a hazard.

CBM is used where the maintenance activity is expensive, either because of the cost of providing the maintenance itself, or because of the disruption that the maintenance activity causes to the operation.

2.6 RCM and TPM

It can be noticed from the evolution of maintenance above, that routine preventative maintenance has served organisations well for the past 40 years. However, in order to maintain the facilities in optimal condition and make cost-effective decisions, new and progressive maintenance techniques needed to be established. This also involves the cooperation of the equipment and process support personnel, equipment operators and the equipment suppliers. These people must work together to eliminate or reduce failures or equipment breakdowns, reduce scheduled downtime, and maximise utilisation, throughput and quality. Two "Best Practice" techniques – RCM and TPM – provide maintenance-oriented frameworks to meet these and other challenges.

2.6.1 Reliability-centred Maintenance (RCM)

RCM grounded theory (Moubray 1997) reveals that this philosophy evolved during the 1950s in the aircraft industry as a result of a number of major reliability studies concerning complex equipment. According to Ross Kennedy (internet 2) these studies were initiated to respond to rising maintenance costs, poor availability, and concern over the effectiveness of traditional time-based preventative maintenance. There tended to be little focus on the actual potential failures and why they should be suppressed, which is the basis of RCM.

In the light of the earlier definition of maintenance, Moubray (1997) defines RCM as "a process used to determine what must be done to ensure that any physical asset continues to do whatever its users want it to do in its present operating context".

The basis of RCM is plant condition, how it changes with time, its diagnosis, its importance to the business and its upkeep. In his theory on RCM, Moubray (1997) indicates that the RCM process entails asking seven questions about the asset or system under review:

- What are the functions and associated performance standards of the asset in its present operating context?
- In what ways does it fail to fulfil its functions?
- What causes each functional failure?
- What happens when each failure occurs?
- In what way does each failure matter?
- What can be done to predict or prevent each failure?
- What should be done if a suitable proactive task cannot be found?

In the sections that follow, the researcher attempts to address the seven questions using grounded theory by Moubray (1997) without divulging into too much detail.

Functions and associated performance standards

Every physical asset has more than one function, falling into two categories – primary ("main" reasons why the asset is acquired) and secondary (in addition to their primary functions) functions. If the objective of maintenance is to ensure that the asset can continue to fulfil these functions, then they must all be identified together with their current desired standards of performance. The secondary functions fall into the following categories:

- Environmental integrity – society's environmental expectations have become a critical feature of the operating context of many assets.
- Safety/structural integrity – most users want to be reasonably sure that their assets will not hurt or kill anyone. Protective devices and functions associated with product contamination and hygiene fall into this category. Some assets also involve supporting some other asset, sub-system or component.

- Control/containment/comfort – many users also want assets to regulate the performance.
- Appearance – this includes functions (like paintwork) to enhance asset visibility for safety reasons, or signs to project an image.
- Protection – As the complexity of physical assets increase, so to does the number of ways they can fail, which has led to a corresponding growth in the variety and severity of failure consequences. Attempts to eliminate or reduce these consequences, has led to the use of automatic protective devices.
- Superfluous functions – this usually happens when equipment has been modified frequently.
- Economy/efficiency – limits are placed on what users are prepared to spend on operating and maintaining assets, which is governed by a combination of three factors:
    - The actual extent of their financial resources;
    - How much they want whatever the asset will do for them; and
    - The availability and cost of competitive ways of achieving the same end.

According to Moubray (1997) any organised system, which is exposed to the real world, will deteriorate. So if deterioration is inevitable, it must be allowed for. This means that when any asset is put into service, it must be able to deliver more than the minimum standard of performance desired by the user. The objective of maintenance is to ensure that assets continue to do what the users want the asset to do – achieved the desired performance. Figure 2.2, shows the relationship between this capability (or inherent reliability) and desired performance. This figure also indicates how these assets can be maintainable.

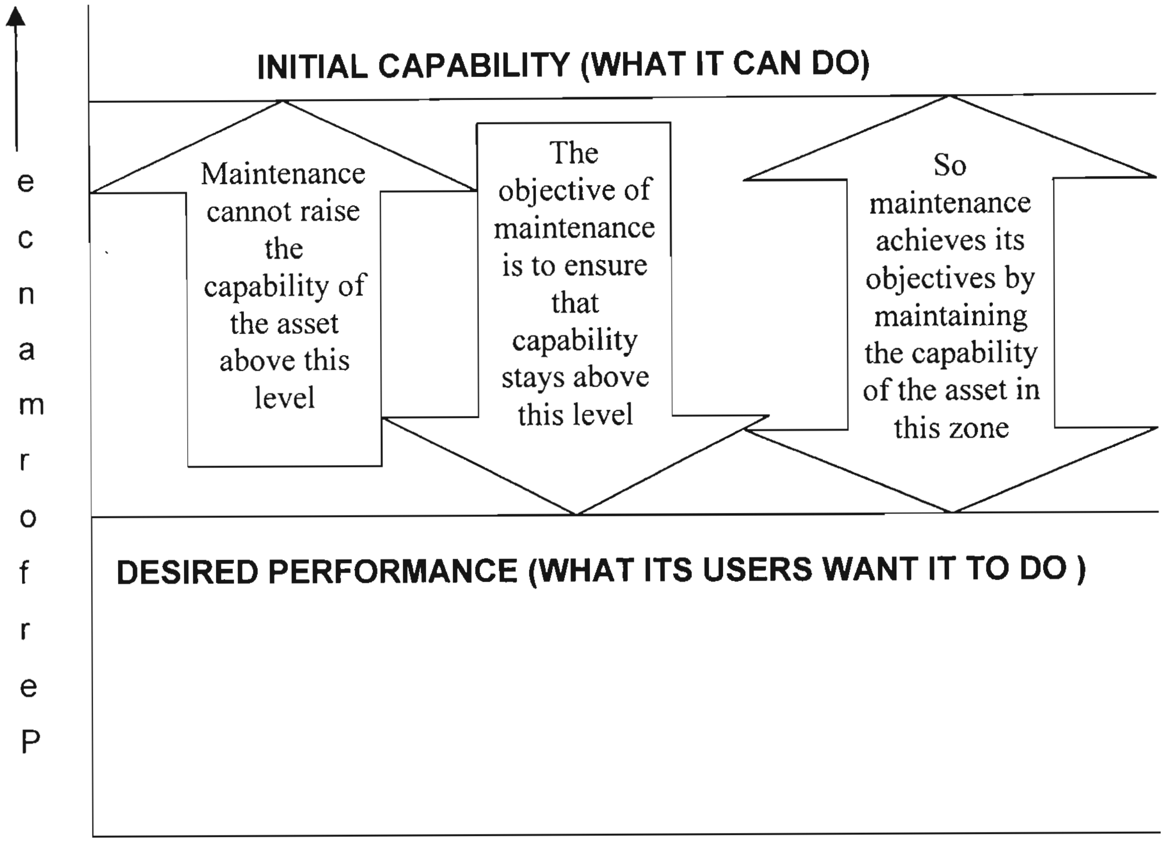


Figure 2.2: A maintainable asset (adapted from *Reliability-centred Maintenance*, John Moubray, 1997)

What failures can occur

If for any reason an asset is unable to do what the user wants, then the user will consider it to have failed. This suggests that maintenance achieves its objectives by adopting a suitable approach to the management of failure (Wilson 1999). In identifying what failures can occur, the RCM process firstly, identifies what circumstances amount to a failed state, and secondly, identifying what events can cause the asset to get into a failed state. In RCM theory (Moubray 1997), failed states are known as functional failures because they occur when an asset is unable to fulfil a function to a standard of performance which is acceptable to the user. This definition encompasses partial failures, where the asset still functions, but at an acceptable level of performance (including situations where the asset cannot sustain acceptable levels of quality or accuracy).

Failure Modes and Effects Analysis (FMEA)

Moubray (1997) defines a failure mode as any event, which is likely to cause a functional failure. So, if maintenance means ensuring that physical assets continue to do whatever their users want them to do, then a comprehensive maintenance program must address all the events that are reasonably likely to threaten that functionality. Failure modes can be classified into one of three groups as follows (Moubray 1997):

1. When capability falls below desired performance. The five principal causes of reduced capability are:
    - Deterioration – which covers all forms of "wear and tear" (fatigue, corrosion, erosion, degradation of insulation, etc).
    - Lubrication failure – which concerns two types of failure modes. Firstly, the lack of lubricant, and secondly, the failure of the lubricant itself.
    - Dirt – which can cause machines to block, stick or jam. It can also be the cause of functional failures, which deal with the appearance of assets, and quality of products.
    - Disassembly – which relate to components of machines falling off, or assemblies or whole machines coming adrift, either because of failure of welds, or soldered joints due to fatigue or corrosion, or failure of threaded components such as bolts or electrical connections, which can fail due to fatigue or corrosion.
    - Human errors – which relate to components incorrectly set or operated by maintenance personnel or operators.

2. When desired performance rises above initial capability. This phenomenon occurs for four reasons, the first three of which embody some kind of human error:
    a. Sustained, deliberate overloading – which occurs when users quickly give in to temptation simply to speed up equipment in response to increased demand for existing products, or when users process a product with different characteristics (such as larger, heavier unit sizes or higher quality standards). This is done in the

belief that they will get more out of their facilities without any increase in capital investment.

b. Sustained, unintentional overloading. Many industries respond to increased demand by undertaking formal "debottlenecking" programs. These programs entail increasing the capability of a production facility to accommodate a new level of desired performance. Usually a few subsystems or components get left out of the overall upgrade program with sometimes devastating results.

c. Sudden, unintentional overloading – which relates to sudden and unintentional increases in applied stress caused by incorrect operation, incorrect assembly or external damage.

d. Incorrect process or packaging materials – which relates to functional failures caused by process materials which are out of specifications, or inadequate or incompatible packaging materials.

3. When the asset is not capable of doing what is wanted from the outset.

Failure effects entails listing failure effects, which describe what happens when each failure mode occurs. These descriptions should include all the information needed to support the evaluation of the consequences of the failure, such as (Moubray 1997):

- What evidence (if any) that the failure has occurred.
- In what ways (if any) it poses a threat to safety or the environment.
- In what ways (if any) it affects production or operations.
- What physical damage (if any) is caused by the failure.
- What must be done to repair the failure.

Failure Consequences

All possible failures affect the organisation in some way, and in each case, the effects are different. There is a lot of time, effort and cost spent to repair these failures. Evident failures can affect organisation in various ways, and they can be categorised into the following three categories in order of importance (Moubray 1997):

1. Safety and environmental consequences.
2. Operational consequences.
3. Non-operational

Moubray suggests many failure management and maintenance techniques and this strategic framework is demonstrated and summarised in figure 2.3.

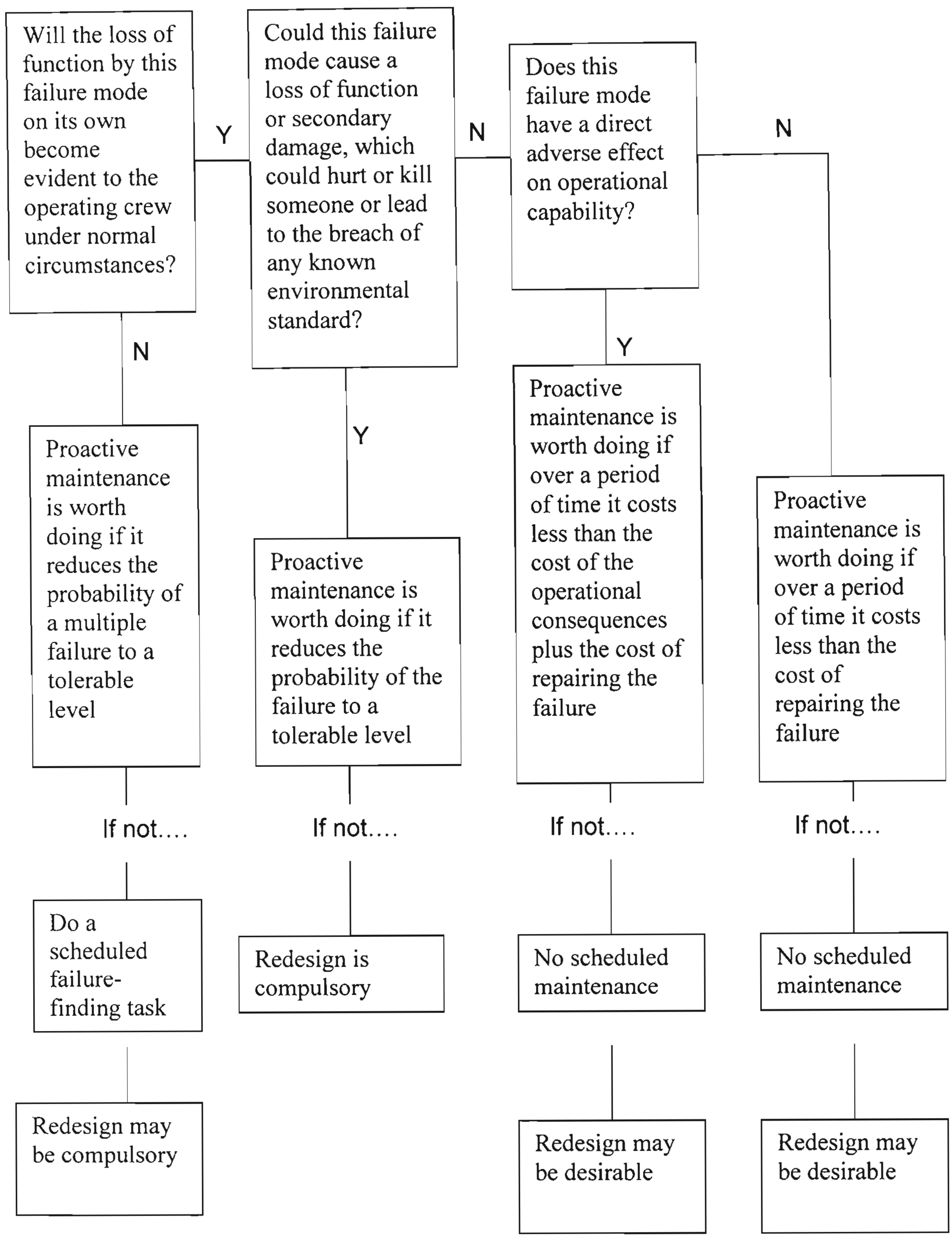


Figure 2.3: The evaluation of failure consequences (adapted from *Reliability-centred Maintenance*, John Moubray, 1997)

Prediction or Prevention of Failures

The actions that can be taken to deal with failures can be divided into two categories:

1. **Proactive tasks** – tasks undertaken before a failure occurs, in order to prevent the item from getting into the failed state. These embrace "predictive" and "preventative" maintenance. RCM uses terms such as scheduled restoration, scheduled discard and on-condition maintenance. On condition tasks are considered first for the following reasons:
    - they can almost always be performed without moving the asset from its installed position – usually while it is in operation, and not interfering with the production process.
    - they identify specific potential failures conditions(see figure 2.4) so corrective action can be clearly defined before work starts – this reduces the amount of repair work to be done, and enables it to be done more quickly.
    - by identifying equipment on the point of potential failure (see figure 2.4), they enable it to realise almost all of its useful life.

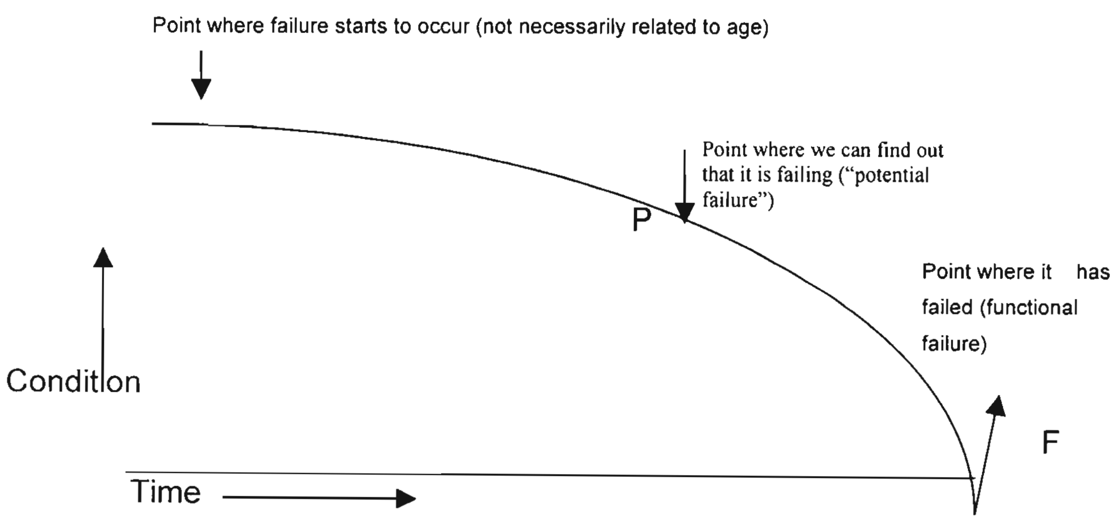


Figure 2.4: Illustration of final stages of failure – the P-F curve (adapted from *Reliability-centred Maintenance*, John Moubray, 1997)

- Scheduled restoration tasks are chosen if a suitable on-condition task cannot be found, and maybe cost-effective for failures with major economic consequences, or if the cost of doing this task is significantly lower than the cost of repairing the functional failure. However, scheduled restoration tasks can only be done when machines have stopped and so affecting the production process. Also, the age limit applies to all items, and many items or components, which might have survived to higher ages, will be removed. These tasks also generate a much higher workload than on-condition tasks.

- Scheduled discard tasks is usually the least cost-effective, and also suffer from the same disadvantages as scheduled restoration tasks.

2. **Default actions** – tasks that deal with the failed state, and are chosen when it is not possible to identify an effective proactive task. These include:

- failure-finding – which entails checking hidden functions to find out whether they have failed;
- redesign – entails making any one-off change to built-in capability of a system, and includes modifications to hardware and once-off changes to procedures; and
- run-to-failure or "operate to failure" – this entails making no effort to anticipate or prevent failure mode to which it is applied, and so those failures are simply allowed to occur and then repaired.

The benefits of RCM are associated with meeting all third generation maintenance expectations as depicted in figure 2.1.

2.6.2 Total Productive Maintenance (TPM)

According to Wilson (1999) TPM differs from other maintenance tools and techniques as it is a fundamentally different approach to the maintenance of business assets, which involve not only the traditional maintenance and engineering departments, but also the production and operations functions in actively working together towards common maintenance goals. In his article on *TPM* (internet 3) Roberts (1997) describes TPM as a maintenance program that evolved from Total Quality Management (TQM) program, using many of the same tools such as employee empowerment, benchmarking, documentation, etc to implement and optimise TPM. According to Pycraft et al. (2000), Nakajima (1988) defines TPM as "*...the productive maintenance carried out by all employees through small group activities* (often called 'quality circles')", where productive maintenance is "...maintenance management which recognises the importance of reliability, maintenance and economic efficiency in plant design".

TPM consists of two main aspects (Wilson 1999), i.e.:

1. A structured approach which uses a number of tools and techniques to achieve very effective plant and machinery, and to measure its effectiveness.
2. A philosophy, which is based upon the empowerment and encouragement of factory floor based personnel from all areas.

This approach is different from the traditional maintenance approach that concentrated on plant and machinery itself, but recognises the importance of people at all levels in all areas have to play if plant and machinery is to be maintained and operated effectively.

The Goals of TPM

In his article on *Examining the Processes of RCM and TPM*, Ross Kennedy (internet 2) mentions that the Quality approach of "prevention at source" was translated to the maintenance environment through the concept of TPM resulting in not only superior availability, reliability and maintainability, but also substantial improvements in capacity with a substantial reduction in both maintenance costs and total operational costs. In the light of this the goals of TPM encompasses the 5 pillars of TPM (some organisations build on these five pillars to 6 and 8 pillars) with the focus on the "6 Major Losses" (see figure 2.5) incorporating the 4 Ms – Man, Machine, Methods and Materials. The discussion of the five pillars of TPM below, has been adapted using theory from various sources (adapted from Pycraft et al. 2000, Examining *the Processes of RCM and TPM* (internet 2), Wilson 1999, and TPM five pillars theory (internet 4):

1. **Improve equipment effectiveness.** This entails examining how facilities are contributing to the effectiveness of the operation by examining all the losses that occur. Loss of effectiveness can be the result of downtime losses, speed losses or defect losses. All TPM activities, including the remaining pillars, results in, or contributes to improved equipment effectiveness. In the light of this, the researcher discusses OEE in more detail in the next section.
2. **Achieve autonomous maintenance.** This increases the involvement and flexibility of use of the operators or users from a passive involvement in maintenance to one in which they will carry out minor setting, maintenance and lubrication activities to keep their equipment in good condition.
3. **Planned maintenance System.** This is concerned with improving maintenance efficiency and effectiveness. To have a fully worked out approach to all maintenance activities, which includes the level of preventative maintenance required for each piece of equipment, the standards for condition-based maintenance and the respective responsibilities of operating staff and maintenance staff.
4. **Maintenance Mindset and Training**. A heavy emphasis is placed here on appropriate and continuous training for both maintenance and operating staff to have all the skills to carry out their roles. This means maintenance training, operations training, leadership training, training about root cause analysis of the major losses, reliability training, etc.
5. **Achieve an early equipment management system**. This goal is directed at going some way to avoiding maintenance altogether by "maintenance prevention" (MP). MP involves tracing all potential maintenance problems back to their root cause and then tries to eliminate them at that point. The system has five major components: maintenance design standards life cycle costing, maintenance database, maintenance and operator involvement in equipment planning and purchasing, and early warning diagnostics.

Overall Equipment Effectiveness (OEE)

Although each organisation may approach TPM in its own unique way, most approaches recognise the importance of measuring and improving overall equipment effectiveness along with the need to reduce both operational and maintenance costs in an environment that promotes continuous improvement. In his article on *So What Do You Know About Your Overall Equipment Effectiveness*, Williamson (internet 5 2000), depicts OEE as the basic measure associated with TPM, incorporating three basic indicators of equipment performance and reliability:

- Availability or uptime (downtime: planned and unplanned)
- Performance efficiency (actual vs. design capacity)
- Rate of quality output

In other words, OEE is used to identify and attack the 6 Major Losses caused by the equipment (a simple model outlining these losses is shown in figure 2.5):

- not being available when needed due to breakdowns or set-up and adjustment losses;
- not running at the optimum rate due to reduced speed or idling and minor stoppage losses; and
- not producing first pass quality output due to defects and rework or start-up losses.

According to Kennedy (internet 2) the international best practice figure for OEE is recognised to be +85% (batch) and +95% (continuous process). The design and installation of equipment as well as how it is operated and maintained affect the OEE. It measures both efficiency (doing things right) and effectiveness (doing the right thing) with equipment. The real benefits of OEE come by using the factors (availability, efficiency and quality) and the actual losses, which lead to root cause analysis of the 6 Major Losses, and eliminating the causes of poor performance.

$$\text{OEE} = \text{availability} \times \text{efficiency} \times \text{quality}$$

$$\text{Availability} = \frac{\text{Net Operating Time}}{\text{Net Available Operating Time}}$$

$$\text{Performance} = \frac{\text{Total Parts produced x Machine cycle Time}}{\text{Net Operating Time}}$$

$$\text{Quality} = \frac{\text{Total Good Parts}}{\text{Total Parts Produced}}$$

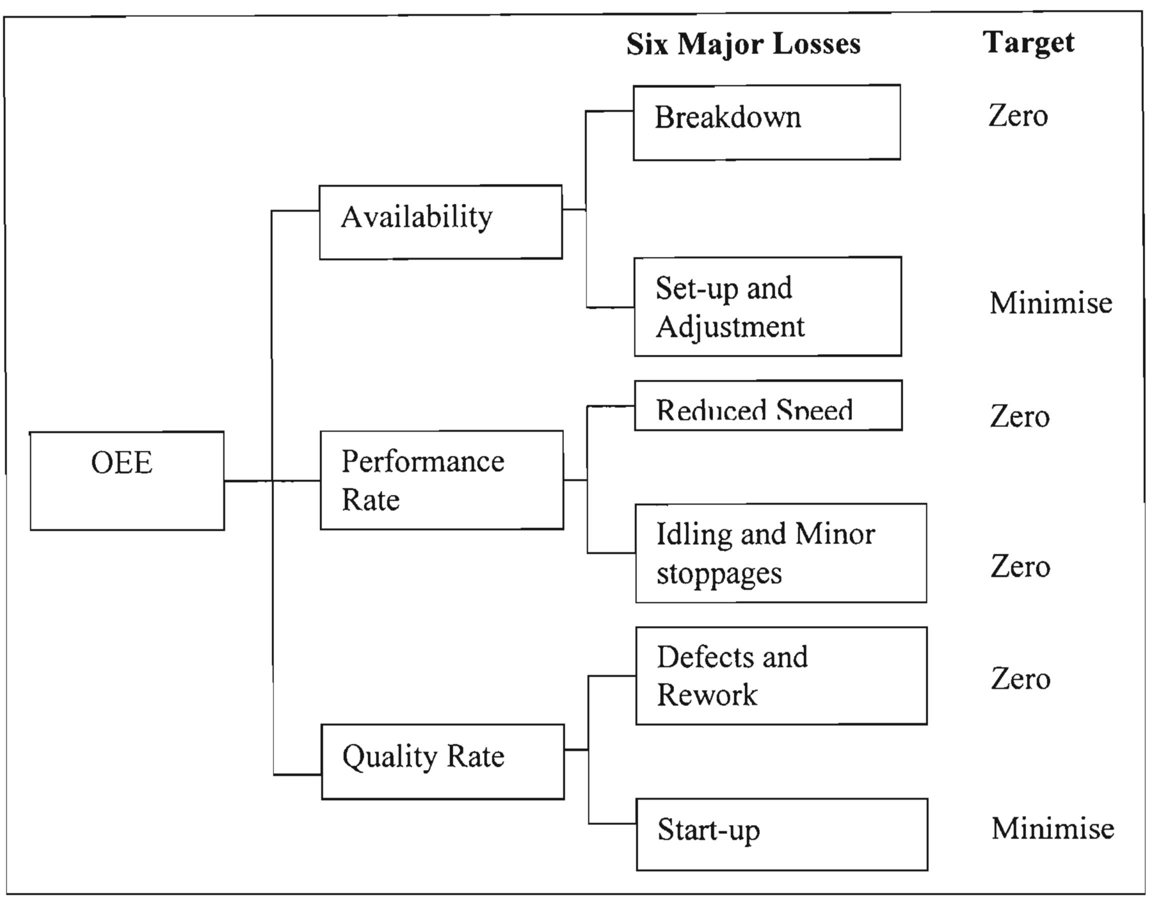


Figure 2.5: Overall Equipment Effectiveness Model (adapted from internet 2)

Root Cause Failure Analysis (RCFA)

This topic has been discussed earlier (section 2.2 Why operations fail) to a lesser degree, and will be expanded on in this section, with a view to create greater awareness of its importance in maintenance and TPM.

As mentioned in the previous section, by tracking and trending the factors of OEE, root cause analysis can be performed and corrective action taken. Ross Kennedy, in his article *Examining the Processes of RCM and TPM* (internet 2) advocates that TPM significantly reduces operational and maintenance costs by focusing on the Root Cause of Failure through the creation of a sense of ownership by the plant and equipment operators, maintainers and support staff to encourage "prevention at source". The tool most commonly used to assist in the search for the root cause is the 5-Whys. Kennedy also states that the 5-Whys is a technique of asking why 5 times recognising that statistically it has been shown that after 5 whys you are most likely to be at the root cause.

TPM theory (internet 2) also indicates that there is a definite relationship between failures and equipment defects in that most failures can be traced back to equipment defects, and hence the aim is to focus on equipment defects so as to eliminate the occurrence of failures and early deterioration.

According to a workshop on *Root Cause Failure Analysis* (2001) out of all the chronic failures that are experienced in a given year, 20% of these represent 80% of a facility's losses. These chronic failures are characterised by low cost and high frequency, and are often small and invisible, but they occur repeatedly and are far more costly than a catastrophic failure. This 80/20 principle is important to understand, if one realises the quantum benefits that can be achieved if the 20% of failures representing 80% of an organisation's losses is investigated.

Effective RCFA cannot be conducted without data, and to get the data, doing a good job of "preserving failure data" (Broussard 1994, internet 6) needs to be done. An appropriate strategy suggested by Broussard to "preserve the failure data" is the 5Ps approach. Failure data of each of the following Ps must be collected as quickly as possible to ensure a successful RCFA:

- Parts – any failed component
- Position – where were things at the time of failure

- Paper – operating conditions at time of failure
- People – who was there, what did they see, hear feel or smell prior to, during, and after the failure.
- Paradigms – what are the cultural norms of the organisation, what do people accept as a way of doing business.

Autonomous maintenance

According to Terry Wireman in his article *Maintenance Prevention - the neglected pillar of TPM* (internet 7) in some organisations operations personnel may perform pre-startup inspections of their equipment, while in other organisations they may do minor maintenance, such as lubrication or adjustments. The goal of involvement is to free up some of the maintenance resources so that they can be deployed in activities requiring higher levels of technical skills, such as predictive maintenance or root cause analysis. The major focus areas of the seven step process is to ensure, assess and restore proper equipment operation

Enrique Mora, in the article *Autonomous Maintenance* (internet 8) explains the seven steps of autonomous maintenance, which is designed to achieve the goal of zero unplanned breakdowns as:

1. Initial cleaning.
2. Eliminate sources of contamination in inaccessible areas.
3. Creation of a checklist for cleaning and lubrication standards.
4. General inspection.
5. Autonomous inspection.
6. Organising and housekeeping.
7. Full implementation Continuity.

The above steps entail raising awareness and understanding of the relationship between equipment conditions and product quality, operation principles of machine and its systems and the ability to determine machine abnormalities and also make improvements.

Improving maintenance efficiency and effectiveness

This includes improving all aspects of maintenance and asset management including spare parts, computerised maintenance management system (CMMS), preventative maintenance, predictive maintenance, maintenance tools, work order system, planned and scheduled maintenance, and equipment histories (internet 9)). The goal is to ensure that the mean time to repair (MTTR) on the equipment is as short as possible, and increasing mean time between failures (MTBF). This allows for maximum uptime and throughput from the asset.

Spares management

From various literatures on asset management, the only reason for keeping a stock of spares is to avoid or reduce the consequences of failure. This relationship between spares and failure consequences hinges on the time it takes to procure spares from suppliers. If the spare is not a stock item this lead-time can dictate the MTTR, and hence the severity of its consequences. On the other hand, the cost for holding spares in stock could be high, tying up considerable amounts of working capital, and a balance must be struck between the cost of holding a spare in stock and the total cost of not holding it.

According to Wilson (1999) under stocking can increase plant downtime and decrease the utilisation of people, and overstocking is expensive on revenue and costs. The skill in evaluating stock levels is in moving the over-expenditure towards the critical spares and parts, but only if they have a history of being under stocked. The objectives of the purchasing function must be carried out effectively, which includes buying:

- The right quality of goods or services
- At the right time
- At the right price
- In the right quantities
- From the right supplier.

Planning and work control

Effective work planning and control is fundamental to an effective maintenance management system. How well maintenance activities are planned and controlled affects all other aspects of maintenance effectiveness and efficiency, from the utilisation of labour to the duration of stoppages. Most of these activities and successful maintenance practices depend a great deal on a robust information system having a CMMS program, consisting of the following basic components:

- Asset register
- Maintenance schedules
- Work specifications
- Corrective and emergency maintenance
- Manpower schedule
- Work orders
- Budget preparation
- Work in progress file
- Spares and stock control
- Plant history
- Cost control

According to *Maintenance and Asset Management* training workshop, presented by Bergh (2003) the objective of work planning and control is to ensure that the contribution made by maintenance to the achievement of the operational, and hence, company business objectives, is fully optimised and achieved by:

- The integration of the maintenance requirement with the plant production schedule to ensure both the achievement of the immediate production target, as well as the long-term life cycle objectives of the plant.
- Planning for the utilisation of maintenance resources to ensure a cost effective maintenance.
- Adherence to the routine maintenance programme and statutory requirement to ensure plant integrity and safety.

- Proper logistics planning to eliminate waste and ensure work quality.

The majority of maintenance work can be planned, which involves preparing job plans and other resources to enable maintenance personnel to perform work quicker and more efficiently. This work has also to be scheduled, which involves creating a schedule for when the work is to be performed. Where planning dealt with the "what" and "how", scheduling deals with the "when" and "who".

Training

Wilson (1999) states that flexibility of staff and working practices has been stated as one of the most desirable attributes that the maintenance organisation should possess. To improve efficiency and to provide job satisfaction implies that carefully nurtured manpower and training strategies will have to be developed. Widening everyone's skills brings increased performance and better communications with production. Working practices change and increases in technical skills and knowledge result in an improved ability to run the plant and equipment – and keep it running.

Training should be provided inline with the development needs for the individual, in line with the future maintenance strategy, and a training programme can be structured to give (Wilson 1999):

- Improved skill levels in the existing core disciplines – to include new aspects of technology where appropriate.
- Improved familiarity with other trades whilst maintaining major involvement in the core trade.
- Improved plant and process knowledge in improved diagnostic skills.
- Improved initiative and self-motivation in designing-out maintenance.

According to Thompson and Strickland (2001) training and retraining are important when a company shifts to a strategy requiring different skills, competitive capabilities, managerial approaches, and operating methods. Training is also strategically important in organisational efforts to build skills-based competencies. It is a key activity in business where technical know-how is changing so rapidly that a company loses its ability to compete unless its skilled people have cutting-edge knowledge and expertise.

Continuous improvement

Continuous improvement, as the name implies, adopts an approach to improving performance, which assumes more and smaller incremental improvement steps (Pycraft 2000). Continuous improvement is also known as kaizen, a Japanese word, and the definition of which is given by Masaaki Imai (who has been one of the main proponents of continuous improvement) as: "Kaizen means improvement. Moreover, it means improvement in personal life, home life, social life and work life. When applied to the workplace, kaizen means continuing improvement involving everyone – managers and workers alike." Effective, planning, analysis, and interpretation continuous improvement tools can include (Chang & Niedzwiecki 1995): Brainstorming, Affinity diagram, matrix diagram, Criteria rating form, check sheet, Force field diagram, and the Cause and Effect diagram.

The most usual way of modelling continuous improvement is the plan, do, check, act cycle (PDCA), by which the stages of problem solving are seen as forming a never-ending cycle. This principle is supported to a great extent by the TQM philosophies, which can be seen as being concerned with (Pycraft 2000):

- meeting the needs and expectations of customers;
- covering all parts of the organisation;
- including every person in the organisation;
- examining all costs which are related to quality;
- getting things "right first time", i.e. designing in quality rather than inspecting it in;
- developing the systems and procedures which support quality and improvement; and
- developing a continuous process of improvement.

W. Edwards Deming (1982) shows 14 steps toward an improvement management, and are mentioned here in the light of components of TQM and continuous improvement:

1. Create constancy of purpose for improvement of product and service with the aim to become competitive and to stay in business.
2. Adopt the new philosophy. We are in a new economic age. We can no longer live with commonly accepted levels of delays, mistakes, defective materials, and defective workmanship.
3. Cease dependence on mass inspection. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price tag. Instead, minimise total cost. Move toward a single supplier for any one time, on a long-term relationship of loyalty and trust.
5. Find problems. Improve constantly and forever every process for planning, production and service. Improve quality and productivity, and thus constantly decrease costs.
6. Institute modern methods of training on the job.
7. Adopt and institute modern methods of supervision of production workers.
8. Drive out fear so that everyone may work effectively for the company.
9. Break down barriers between staff areas or departments. People in research, design, sales, and production must work as a team, to foresee problems of production that may be encountered with various materials and specifications.
10. Eliminate numerical goals, posters, and slogans for he workforce, asking for new levels of productivity without providing methods.
11. Eliminate work standards that prescribe numerical quotas.
12. Remove barriers that rob people of pride of workmanship.
13. Institute a vigorous program of education and self-improvement for everyone.
14. Create a structure in top management that will push everyday on the above 13 points – plan of action.

According to Thompson and Strickland (2001) effective use of TQM/continuous improvement techniques is a valuable asset in a company's portfolio – one that can produce important competitive capabilities (in product design, improved efficiency, cycle time, lower cost, better product quality and reliability, service, and greater customer satisfaction) and is an important tool on how to execute a strategy more proficiently.

20 Keys Workplace Improvement System

Professor Iwao Kobayashi (Columbus Stainless intranet 10) says with regard to the 20 Keys Workplace improvement programme, "When all employees are aware of the company's position in relation to world best practices, a true feeling of competition is developed on every level and everyone becomes aligned in their efforts to improve." This 20 Keys improvement programme (Columbus Stainless intranet 10) is a Workplace Improvement Programme for all employees:

- Comprising of 20 key methods require to strengthen the organisation's delivery system.
- Utilising simple drawings to benchmark the organisation against best practices in the world.
- Creating an image (or view) throughout the organisation of what can be achieved.
- Enabling every unit in the organisation to evaluate their capability and set specific improvement goals.
- Providing a methodology to achieve top management's goals in the workplace.
- Involving all employees in the accomplishment of the super ordinate goal – 20 point improvement in 4 years to double productivity.
- Integrating all the best improvement methods to eliminate waste.
- Focussing on making products and services better, faster and cheaper.
- Energising and motivating employees to achieve improvement goals.

2.7 World Class Maintenance

Ingalls (2000) in his internet article, *Changing Maintenance Practices*, (internet 1) mentions that regardless of who does maintenance, whether it is a specialised skilled or multiskilled tradesperson or a highly trained operator, solid maintenance practices are the keystone to World Class Maintenance, which leads to World Class operations. According to theory Ingalls (2000) and an article by Lester and Fischer (1992) *Building a world-class maintenance organisation* best maintenance has its foundations in Best Maintenance Practices, which include:

- *Leadership and Policy Development.* World Class Maintenance relies on leadership:
    - providing direction, focus and support;
    - establishing a clear mission and vision supportive of the organisation's direction and goals;
    - establishing the policies and expectations that serve to guide maintenance and the total organisation in supporting maintenance activities;
    - setting the framework for maintenance to improve its effectiveness and efficiency; and
    - identifying and addressing resources issues that could prevent improvements from taking place
- *Organisational Structure.* Maintenance organisations function at three major levels: organisational level (functional and structural relationships), process level (work activities), and job performer level (individual worker). The ineffectiveness of one level could negatively impact another level.
- *Inventory control.* The purpose of this area is to refine the maintenance stores and acquisition process to streamline parts appropriation – focused on the right parts in the right place at the right time. This would involve standardised stores and inventory practices, to improve the process of requested parts to reduce wasted effort and inactivity.
- *Computerised Maintenance Management System (CMMS).* Successful maintenance practices depend a great deal on a robust information CMMS

system. The modules should be consistent with industry standards, which include the following areas:

- Equipment data management.
- Work-order control.
- Preventative maintenance.
- Inventory control.
- Documentation control.
- System security.
- Ease of use.
- Reports.
- User configuration and measured results (or) metrics.

- *Preventative maintenance.* This should be established for all key equipment, incorporating high quality checklists and inspections sheets. The most significant activity to occur is inspection, which should lead to early detection and correction.
- *Predictive maintenance.* This should be established for all primary equipment, incorporating strength in data analysis, and consistency in performance of this activity.
- *Planning and Scheduling.* The lack of organised processes and standardised procedures can significantly restrict a maintenance operation from meeting its objectives of servicing the needs of the organisation. Increasing productivity or value-added work of maintenance personnel depends a great deal on properly planned activities.
- *Work Flow.* The work-order is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.
- *Financial control.* This deals with the fiscal control procedures, and may include maintenance budget control, contractor cost monitoring, overall labour and material cost control, and decisions on asset repair/replacement.
- *Operational involvement.* This involves operator involvement in performance of basic care type maintenance activities, and may be in the

form of TPM or some other structured process to encourage ownership, involvement, and improve equipment reliability.

- *Staffing development.* Traditional views of restrictive job requirements and duties will have to be replaced with more flexibility and higher levels of skills. People will perform successfully if they are capable, have well defined job roles, know what is expected of them, have the skills and knowledge as well as the tools and resources to perform, and receive feedback and rewards for good performance.
- *Continuous improvement.* This is best described as constantly striving for better ways to do things. It is creating discomfort with the status quo and striving towards excellence through small, incremental steps. This often involves benchmarking, auditing and monitoring one's operation to others to reduce the possibility of slippage and not following standards.

It is important to measure these practices to see how well they perform in an organisation, and how well the maintenance strategy enables the rest of the organisation to meet its goals and objectives.

2.8 Maintenance Management Strategy

According to Strickland and Thompson (2001) strategies represent management's answers to *how* to achieve objectives and *how* to pursue the organisation's business mission and vision. There is a strategy for the company and all of its businesses as a whole (corporate strategy). There is a strategy for each separate business the company has diversified into (business strategy). There is a strategy for each specific functional unit within a business (functional strategy). Then there is a strategy for basic operating units – plants and departments within functional areas (operating strategy). In order to pursue any strategy the strategic management process, as shown in figure 2.6, can be adopted.

Since the maintenance function is the management's game plan for running the maintenance activity of the business, we are concerned here with the formulation of a functional strategy. The maintenance management strategy must be able to support the company's overall business strategy and competitive approach.

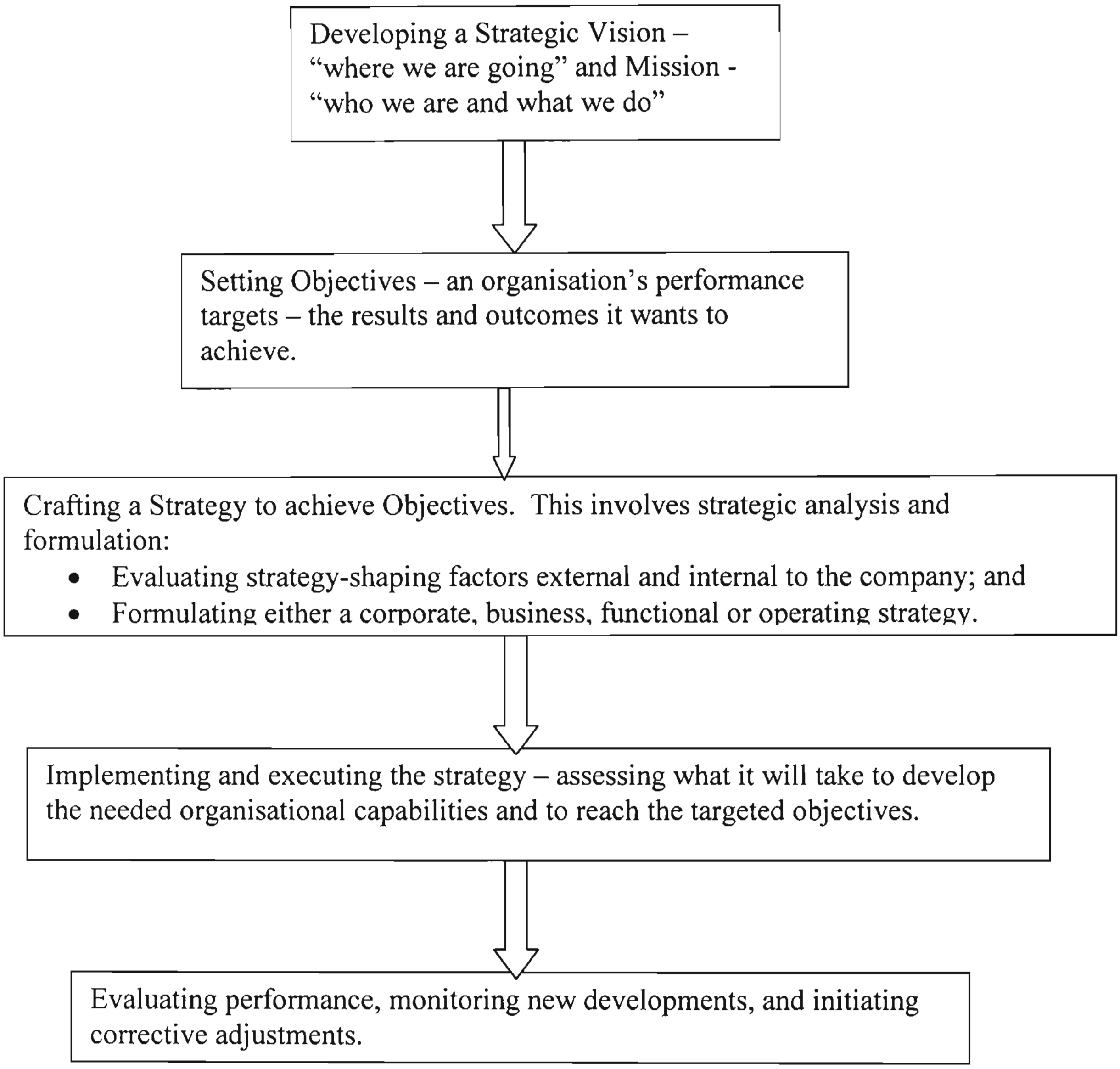


Figure 2.6: The Strategic Management Process (Adapted from Strickland and Thompson, *Crafting and Executing Strategy*, 2001)

According to Wilson (1999) in the past, maintenance has rated a relatively low priority among those strategic policy matters considered at company Board level. Therefore, maintenance has tended to fulfil its role by having to respond to unforeseen problems, rather than developing in a proactive way. Over the last decade maintenance managers have been making strenuous efforts to recover from this approach in order that their maintenance strategy should become policy led rather than problem led.

The key performance area or fundamental philosophy and principle underpinning the correct approach to maintenance management is the continuous satisfaction of customer needs. Customer satisfaction will be determined by the organisation's ability to satisfy its customers' quality, service levels, equipment availability, equipment output performance, responsiveness, communications, reliability, availability and price requirements. Wilson (1999) states that the preparation of the maintenance strategy seeks to consider the objectives and priorities of the company, and then to evaluate and define how the maintenance function should respond and be organised in supporting those needs. Before proceeding on a project for developing strategy, an appreciation of where maintenance is placed in relation to the following is required:

1. ***The business plans.*** The question to be asked here is "how will the maintenance strategy operate within the framework of the overall business plan?". A company's objectives, organisation and policy, change frequently and need to be reviewed regularly in relation to the external environment, and in light of the pressures of the organisation. The process review, is usually arranged at three levels:
    a. Corporate planning.
    b. 3 – 5 year plan.
    c. Annual plan – budgets.
2. ***Corporate philosophy.*** This philosophy shapes the application of the business forces to the business plans and include:
    a. To remain competitive in the market.
    b. To increase efficiency and optimise costs.
    c. To increase the profitability of a quality product.
    d. To maximise plant utilisation and capability and retain high asset value.
    e. To develop people.

The prime objective of the maintenance strategy must be compatible with these and the production philosophy, and be directed towards company viability and profitability.

3. ***Production philosophy.*** The emphasis shown by production is on the benefits of productivity and immediate delivery. This is also what is expected from maintenance, but the benefits of good maintenance strategies are usually obtained over a longer timescale. Whilst the maintenance strategy is determined largely by production needs, the approach of production "today" at the risk of a loss of two days production "next month" is a philosophy which is sometimes at odds with both correct maintenance thinking and corporate philosophy.
4. ***Quality and safety.*** Adopting a Total Quality approach to managing maintenance will improve teamwork, performance and safety, as well as reducing the risk of environmental damage. This includes conforming to ISO 9000 standards, reducing costs, and improved customer relationships.
5. ***Customers.*** A maintenance strategy will be considered effective in the long run only if it both focuses on the customer's requirements, and meets them. Customer focus includes improving relationships between customer and maintenance function on issues mentioned earlier such as quality, service levels, equipment availability, equipment output performance, responsiveness, communications, reliability, availability and price requirements.

The range of maintenance elements to be considered in strategy are therefore many and varied. According to Wilson (1999) they include all the maintenance policies, practices and methods used in assessing what should be done, why it should be done, and who should do it. They also include legislation, procedures, organisation and control. Figure 2.7 shows a cross section of the range of maintenance policy sectors and their practices.

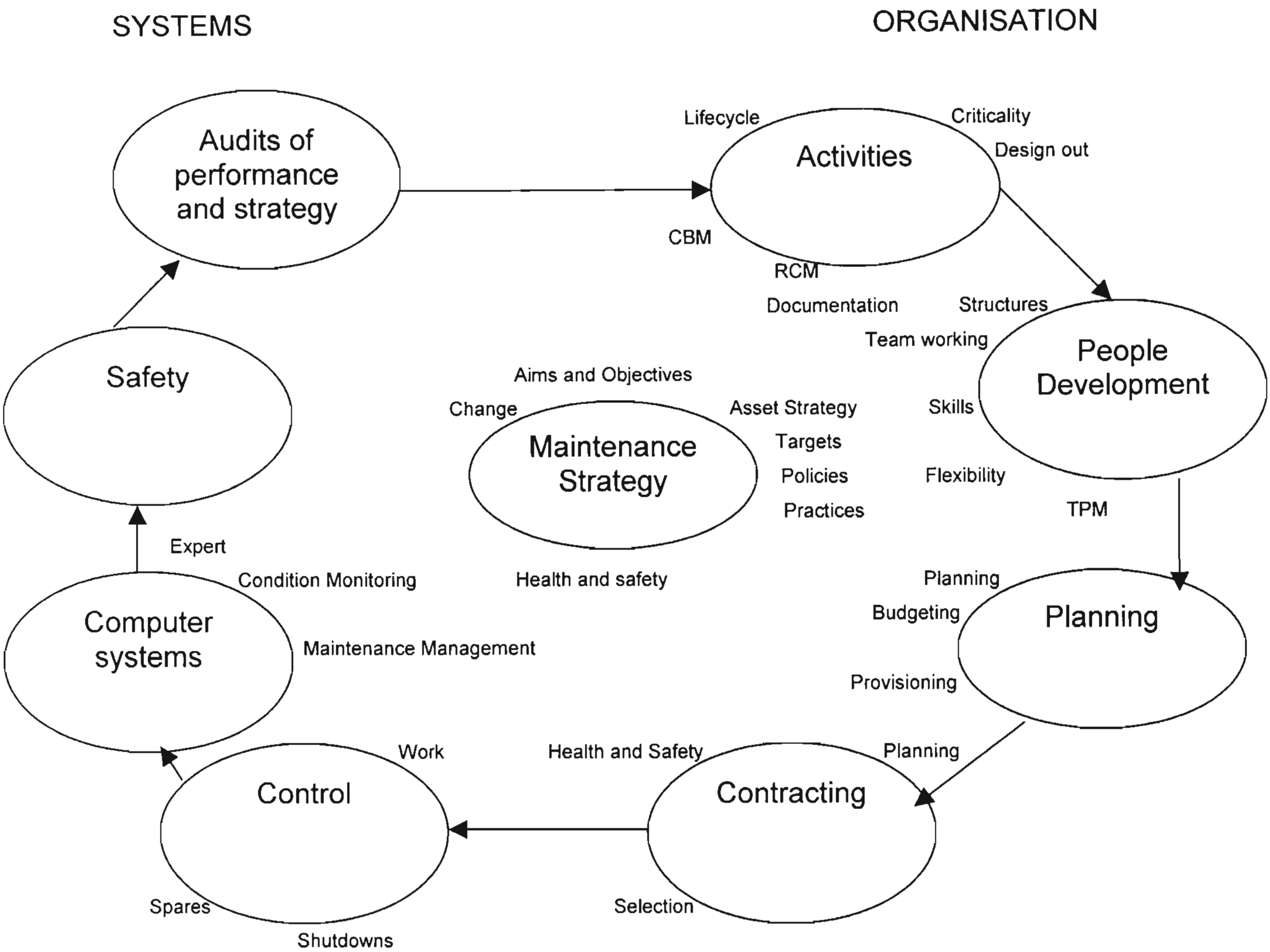


Figure 2.7: The range of maintenance policy sectors and their practices (*Asset Maintenance Management*, Alan Wilson,1999)

2.9 Chapter Summary

In order to develop or change and implement a good maintenance strategy, the various maintenance activities relating to the maintenance function must be known. An efficient and effective maintenance mix incorporating the different approaches to maintenance – RTB, PM and CBM – into a maintenance framework, utilising maintenance practices from RCM, TPM and World-class Maintenance philosophies can be implemented. This maintenance mix, which covers the range of maintenance policy sectors and their practices as depicted in figure 2.7, can be focused on the delivery and implementation of maintenance practices that maximise the contribution of assets to an organisation's profitability. Asset availability can be increased with improvements in reliability, efficiency, effectiveness, safety, costs and OEE. "Arrangement and organising all necessary required materials, manpower, tools and equipment, methods and money before hand and on time, enables proper execution of maintenance plans that reduces delays and improves availability and reliability of machinery and contribute to the low cost of producing products (cost/unit of production)." (*Maintenance and Asset Management journal*, vol 17, no5, 2002) Figure 2.8 has been adopted to show this.

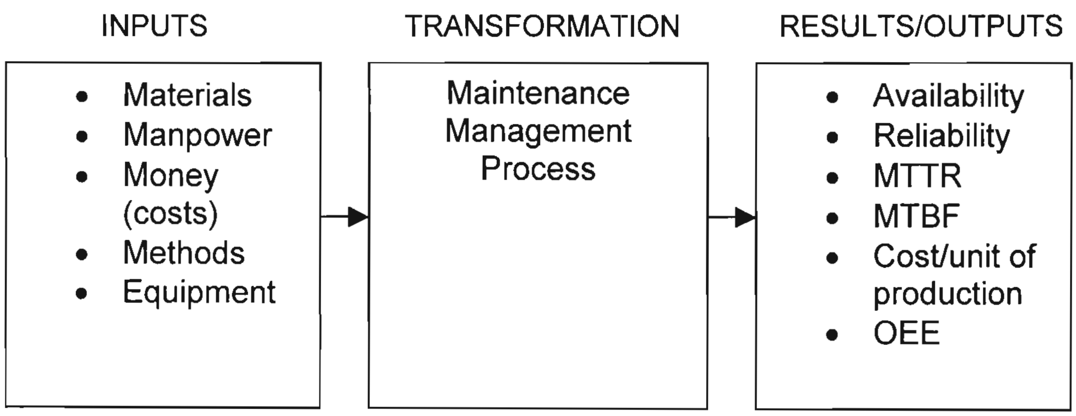


Figure 2.8: The input-transformation-output Maintenance Mix (adapted from the *Maintenance and Asset management journal*, vol 17, no. 5, 2002)

Chapter Three – Columbus Stainless's Maintenance Strategies

3.1 Introduction

This chapter presents the latest available *Columbus Stainless Corporate Maintenance Strategy* that was compiled on February 2001. The plant-specific maintenance strategies of the Hotmill as contained in the *Rolling Mills Maintenance Plan* as per August 2000 (one of the plants at the hot end of the organisation is also presented. The Steelplant (another plant at the hot end of the organisation) does not have a documented maintenance plan, and as such will not be presented in this chapter. The description of the maintenance strategies presented in this chapter, is a reflection of the exact information content as contained in the strategies.

3.2 Columbus Stainless Corporate Maintenance Strategy (CSCMS)

The information content of this maintenance strategy consists of the exact content as reflected in the Corporate Maintenance strategy and includes the following:

1.Scope:

This policy applies to Maintenance applicable throughout Columbus Stainless, to all machinery, plant and processes that directly affect product quality, and the safety and health of personnel.

2. Purpose:

To institute and maintain a corporate maintenance policy and strategy for the Company, guiding and assisting plant areas in maintenance execution activities, whilst supporting the Operations Department with acceptable levels of reliability, availability and safety, at cost levels as specified within the overall Business Plan.

3. Maintenance defined:

"A cause to continue"

All processes and actions necessary to ensure optimal machine functionality, as per business requirements. [Functionality includes availability, reliability, accuracy of operation and safety]

4. Responsibility:

It remains the responsibility of the Business Manager per plant area to implement a maintenance plan, systems and procedures for maintenance and to ensure the requirements herein are met.

5. Operational Departments:

It remains the responsibility of the General Manager Engineering, in consultation with the relevant plant engineers, to define the standard, extent and frequency of maintenance and to ensure continuous optimisation of this document. CES will supply support and guidance when and where required.

6. Abbreviations:

AMIS	Asset Management Information Systems
CBM	Condition Based Maintenance
CES	Central Engineering Services
CMMS	Computerised Maintenance Management System
CWS	Central Workshops
ECP	Engineering Change Proposal
HR	Human Resources
HT	High Tension
KPA	Key Performance Areas
KPI	Key Performance Indicators
LCC	Life Cycle Costing
LRU	Line Replaceable Unit
MSA	Measurement System Analysis
MTBF	Mean time Between Failure

MTTR	Mean Time To Repair
PM	Planned Maintenance
PMO	Planned Maintenance Officer
RAM	Reliability and Availability
RCFA	Root Cause Failure Analysis
RCM	Reliability Centred Maintenance
RCS	Reliability Centred Spares
RIC	Rotable Interchangeable Unit
SKS	Steelplant Coding System ("Stahlwerk Kennzeichenn System")
SPC	Statistical Process Control
TPM	Total Productive Maintenance

7. Terminology / definitions:

Autonomous	A process to involve the operator in the care of his or her own equipment.	
Kaikaku	Non linear improvement	
Kanban	Process pull methodology	
Stage 1 maintenance	Equipment monitoring, minor corrective work, early fault detection, lubrication, troubleshooting, inspect & report	Plant maintenance & 1st line Maintenance teams
Stage 2 maintenance	Condition monitoring, overhaul / rebuild, reliability improvement, shutdown PM, major corrective work, modification / design-out	Central Engineering, specialist maintenance teams
Stage 3 maintenance	Major refurbishments, technology developments, projects	External & internal specialist groups
Maintainer	Any individual partaking in any maintenance activity	
Maintenance Plan	Business area detailed equipment, in line with this strategy	
Opportunistic Maintenance	Applying maintenance resources to unplanned available time	
Planned Maintenance	Long term and short term planning of maintenance tasks and	

	resources	
Predictive	Condition based	} Operational parallel
Preventive	Schedule & analysis based	
RCM	A systematic analysis approach whereby the equipment design is evaluated in terms of possible failures, the consequences of these failures and the recommended maintenance procedure that should be implemented.	
Technology Management	The management of the 3 aspects that as a whole constitutes technology – (1) People and People Structures, (2) Science or Knowledge of Technology, (3) Tools or Artefacts of Technology (Materials, Machines, Physical Processes, Facilities). This is achieved by understanding, developing and controlling the relation between the three aspects: People and Science/Knowledge Relationship: people develop new know-how by research and development and existing know-how are taught by training and skill development. People and Tool Relationship: develop, maintain and improve skills, business processes and craftsmanship. Science/Knowledge and Tool Relationship: develop, maintain and improve algorithms, procedures, rules, guidelines and physical processes.	

8. Applicable documents:

Applicable WSI's (Work Standing Instruction)

Asset Replacement Policy

Condition Monitoring Policy

Configuration Management Procedure

CAPEX policy

Environmental policy

KPA / KPI document

Labour Hire Procedure

Maintenance Role Skills Matrix

OEE measurement

OHSACT (legal) requirements

QS9000 / maintenance relation matrix

Quality Policy

RCM Guideline

Safety Policy

Shutdown Procedure

Spares Refurbishment Procedure

Stockholding / Spares Management Policy

20 Keys improvement techniques

9. Maintenance corporate policy:

To perform cost effective maintenance, ensuring optimal equipment functionality and process control, in order to exceed customer requirements.

This is achieved by:

- Applying a *reliability centred maintenance* philosophy
- Utilising *spares management* techniques
- Continuous *measurement and control of equipment & processes*
- Equipment *life cycle management*
- Ensuring effective usage of *information*
- Utilising *1st line maintenance* principles
- Utilising *self sufficient teams*
- *Developing people* through coordinated maintenance *training* programs
- Ensuring *continuous improvement* through best practice techniques and by fostering *a learning culture*
- Incorporating *QS9000* principles

Quality Planning → Quality Maintenance → Quality Products

This policy supports all aspects of Columbus' HR, 20 Keys, Quality, Safety, Environmental Policies and Legal requirements.

10. Maintenance Management Planning:

10.1 <u>The maintenance organisation.</u>

The organisational structure supports the current Business Plan and Drivers. This structure can be optimised by a consensus agreement or by a change in operational workload. Currently a formal structure exists, including plant maintenance as part of the operations department, per plant area. A standardised structure down to maintainer level, including accountabilities and responsibilities, is available and may be implemented.

10.2 Manpower.

The manpower strengths, types and applications are derived from the maintenance plan and workload as required by the equipment, per plant area.

10.2.1. 1st Line Maintenance

Production personnel are trained and equipped to perform 1st line maintenance tasks, e.g. elimination of the 3 maintenance evils. This originated in order to free the maintainer to perform more complex and critical maintenance tasks. Further strategies are:

- Create asset care culture for operations personnel
- Optimise manpower utilisation
- Support a philosophy of component exchange
- Plant specific 1st line maintenance tasks, required tools and Work Instructions are specified per area
- 1st line maintainer may be trained and be declared competent to a Level 3, depending on task complexity
- Assistance on required tasks to be incorporated (across departmental boundaries)
- 1st line maintainers empowered to accept responsibility and will be held accountable

10.2.2. Self Sufficient Teams

A team that encompasses all the necessary skills and resources to operate and maintain the relevant equipment and be able to function without a supervisor

- Availability of optimum maintenance skills for relevant tasks

- Access to other specialist functions and technology at all times
- Sufficient infrastructure to ensure access to required systems and information sources

10.2.3. Maintenance training programs

- The following maintenance related training courses have been formulated and are available to all relevant personnel, in line with the maintenance role skills matrix:
  - 20 Keys (detail on key 9)
  - 'AMIS' (Work Planning and control)
  - CMMS
  - Health & Safety
  - Maintenance Strategy
  - OHSACT Introduction
  - QS9000
  - RCFA
  - RCM 3-day
  - RCS
  - SKS
  - 'Spares finder' (Internet spares search facility)
- Plant specific technical staff are made available for training (opportunity for knowledge upliftment)
- All maintainers are taking part in a knowledge exchange program
- All maintainers are developed in terms of a recognised career path
- The roles of maintenance advisors and specialists are fostered and encouraged

10.2.4. Role clarification

- Generic roles have been developed for the following maintenance staff:
  - Artisans
  - Consultants
  - Engineers

- Master artisans
- Millwrights
- Planners
- Planned Maintenance Officers
- Specialists
- Team Managers
- Technicians

10.3 Resources

The tools, materials, labour, etc. required are to be specified and optimised by the responsible appointed Engineer, per plant area.

10.3.1. Labour Application

- External labour hire is limited to:
  - Shutdowns
  - Long term labour base and work base variances (sickness, studies)
  - Major breakdowns
- External labour hire per specific job position shall not exceed 6 months. If the job deems this necessary, a special contract or temporary employment will be considered after investigation.
- External labour hire is controlled via Central Engineering Services (requests, approval).
- Internal labour application at other plant areas will take precedence over sourcing external labour (also in the event of overtime to be worked).
- Prestige centralised labour pool exists for optimal labour application.
- Ongoing skills development (other than formal training).

10.3.2. Spares Management

- Effective spares management techniques are in place to reduce downtime risk, drive plant availability and reduce costs.
- Quality control is enforced for spares procurement purposes.
- All maintenance spares are allocated with an item code.

- The Main Store facility operates on a 24 hour basis
- Satellite stores are kept to a minimum and contain only plant specific consumable spares. Items kept in these stores are visual and available to all areas of the business.
- Spares management remains each plant's responsibility (dayshift maintenance).
- Maintenance spares usage (excluding consumables) is linked to the relevant jobcard for costing and history purposes.
- The RCS technique is accepted as a business standard for optimal spares holding.
- The Internet spares sourcing resource, "sparesfinder.com", is being utilised for own plant, national and international spares searching exercises.

10.3.3. Tools

- Prescribed tool lists are available for all maintenance levels / categories (internal labour). Tools in accordance with these lists are purchased by the relevant personnel and subsidised by the company. Ad hoc audits are performed on cleanliness, condition and availability of these tools.
- Standardised tool lists are available for all external trades (tools to be brought on site with person)

10.4 Financing

Maintenance is financed by means of budgets, provisions and Capital Expenditure Applications. Assets are to be replaced in accordance with the Asset Replacement policy.

11. Asset care / strategy implemented aids:

11.1 RCM

- Every plant applies the RCM II philosophy
- RCM is done on all new equipment units installed (before hand-over to production)
- Business managers are responsible for driving RCM for their respective plants

- RCM is coordinated from Central Engineering
- A plant technical audit and central methodology audit is performed on all analyses to ensure validity and correctness
- Savings from RCM analyses are calculated and communicated to the business
- RCM analysis results are integrated with the CMMS
- A detailed RCM guideline is available for reference purposes

11.2 Life Cycle Management

- Systems aligned with business processes in order to fulfil equipment life cycle studies
- Dedicated team for life cycle analysis is available
- Guideline available for reference purposes

11.3 Continuous improvement techniques (including fostering a learning culture)

- Continuous drive for people upliftment
- Relevant knowledge is systemised
- Knowledge exchange system has been established ("virtual engineer")
- RCFA (kill the root cause), backed by facilitation team
- Condition Based Maintenance
- Succession career planning
- Modification control body for optimised ECP's
- Availability of a dedicated engineering body for:
    - Maintaining engineering standards and procedures
    - The law and maintenance
    - Standardisation
    - Consultation ("virtual engineer")
    - Technology management
- Configuration management (refer to procedure)
- Visibility and preservation of maintenance information (systems and Intranet)
- Transparency of maintenance related problems / incidents

- Continuous alignment of systems to business processes

11.4 Condition Monitoring

- Centralised support function with laboratory facilities
- Plants drive 1st line condition monitoring (basic usage of senses)
- Continuous move towards CBM and on-line condition monitoring
- Condition monitoring guideline exists, defining scope of work

11.5 CMMS

- CMMS in operation and available to all maintainers via personal computers and / or walk-in-centres
- Current system, Pipaq, is integrated with Configuration Management, Stores, Commercial and partly Finance
- CMMS support is outsourced to Pilog (on-site support on performance basis)
- System is flexible for customisation, in line with optimised business rules

11.6 ECP process

A formal equipment modification process (functionality on CMMS) is being utilised for all engineering changes on equipment. The Configuration Management Department is coordinating the process.

11.7 Maintenance plan development (review, optimise and control)

- The maintenance plan, per plant area, shall support the corporate maintenance strategy, with regards to the type of equipment. Thus, depending on required plant utilisation, each equipment unit has a unique maintenance plan. The equipment and application of the equipment therefore determines the maintenance plan. The following strategies may be employed in this plan:
    - Scheduled maintenance (preventive)
    - Condition based maintenance (predictive)
    - Time based maintenance (overhaul, replace)

- Breakdown maintenance (corrective)
- Design-out maintenance

12. Maintenance effectiveness optimisation:

12.1 Shutdown management

➢ Plants are committed to:
  - Perform all planned work, as per pre-shutdown meeting
  - Optimise shutdowns to ensure required throughput and quality
  - Perform opportunistic maintenance when possible (off-line task planning in place).

➢ Corporate tool (system) available for shutdown planning.

➢ A shutdown schedule is available on the corporate information network and developed in line with the throughput strategy (production plan), in terms of:
  - Legal issues (OHSACT compliance)
  - Specific maintenance requirements, e.g. Kanban, Kaikaku, Kaizen projects.

➢ Supplier agreement drawn up with Stores Management for spares delivery.

➢ A shutdown procedure and guideline is available for reference to ensure quality shutdown principles plant wide.

➢ The company participates in and is a member of the national Shutdown Network Forum for internal shutdown and external labour optimisation purposes.

➢ Shutdowns are monitored on an ad-hoc basis (by engineering body) for standardisation and optimisation purposes.

12.2 Production (PP&C) interface

Effective integration with PP&C for optimised downtime, shutdowns, program changes, and no material purposes.

12.3 Audits & benchmarking

12.3.1. Maintenance

- Hard audit – Index and audit parameters of KPA's (once per annum)
- Soft audit – survey of maintenance perception of people (twice per annum)
- External (technical) audit (every two to three years)
- SAMA audit for maintenance excellence (once per annum)
- Benchmarking with external industry related companies on ad-hoc basis – national & international

12.3.2. Labour Hire

- On site survey of hired labour (work relevance, qualifications, validation of induction and medical status, competence, etc.)

12.3.3. Shutdowns

- Ad-hoc shutdown audits (pre- and post-planning, execution, history, betterment, standards, etc.)

12.3.4. RCM

- Re-visit / audit analysis 6 months to a year after implementation

12.3.5. CMMS

- System integrity audits in conjunction with Systems House and outsource partner, Pilog
- Data integrity audits
- Re-evaluate system to business fit every 3 to 5 years

12.4 Analysis, measurement and reporting

- Continuous analysis, measurement and control for ongoing goal and policy alignment
- Establish cost effectiveness
- Measurement and reporting as per established KPA and KPI documents
- Relevant engineering indicators and results are made visible to the business

- Training structures in place on interpretation of the relevant indicators
- Corrective action is implemented from findings of analyses
- Decision Support function available for:
  - Statistical analysis
  - RAM modelling and analysis
  - Cost and risk impact analysis
  - KPI discrepancies and investigations
  - Case studies

12.5 <u>Maintenance information usage</u>

- Maintenance information shall:
  - Allow for effective management decisions
  - Be structured as such to enable improvement of maintenance practices
  - Be available and made available for the purposes of analyses
  - Be accurate and indicate the best reflection of reality
- All maintainable and operable equipment are registered on the CMMS database and identified by either SKS or RIC number
- All system actions / transactions are linked to a relevant SKS / RIC number
- Each plant takes ownership of his respective information
- New information systems shall be as such where integration is possible to existing systems and shall be in line with this strategy
- All users of information are trained and have access to relevant hardware, software and information
- Security access structures are in place for protection of sensitive information
- A single point of entry system has been established for ease of man machine interface

12.6 <u>Planned maintenance</u>

- Target indices for the company are:

- Planned to unplanned ratio = 70%: 30%
- Schedules as % of total tasks = 40%
- Breakdowns as % of total tasks = 10%
- Tasks not done as % of total tasks = 5%
- Artisan to planner ratio = 15: 1
- Job card turnaround time = 7 working days
- Outstanding work in crew weeks = 2 weeks

➢ A "maintenance healthy" indicator has been developed for individual plant or overall company measurement

➢ Planned maintenance standards for the company are based on functional best practice concepts.

13. Maintenance support services:

Generic guidelines have been drawn up in conjunction with the following support service areas:

➢ HT

➢ Stores

➢ CES
- Fleet Control
- Central Workshops
- Condition Monitoring
- Maintenance Systems
- Cranes
- Specialists
- PMO's

➢ Commercial

➢ Risk Control

➢ Projects
- Drawing office
- Configuration Management
- In plant projects (capital projects)

➢ HR

- Utilities
- Systems House
- Protection Services
- Technical, Measurement & Control
- Production (1st line)
- Clinic
- Finance

14. Safety, Health, Environment and Quality:

- Safety: full adherence to policy and standards
- Health: full adherence to policy and standards
- Environmental: full adherence to policy and standards
- Quality (QS9000):
  - All critical equipment is identified and registered
  - A QS9000 / maintenance relational matrix has been developed
  - SPC is utilised for identifying problematic equipment / deviations (early warning system)
  - RCFA techniques are applied to eliminate recurring problems
  - The MSA program is being supported and driven
  - Full adherence to policy and standards
- 20 Keys: full adherence to guidelines

3.3 Hotmill Maintenance Plan (HMMP)

1. What is expected of maintenance? – The maintenance definition

- To Support operations of the Hot Mill in an efficient and professional manner in achievement of the production objectives.
- To ensure all assets operate at required performance and availability levels for their planned economic lives.
- To act to increase the reliability and performance of assets through a program of continuous improvement.
- To manage human and money resources in a way which maximises value to both the individual and the Hot Mill.

2. What performance is required from the maintenance process

In essence maintenance means "a cause to continue". This implicates that actions and processes must be align as to cause equipment and other maintenance processes to continue with their intended functions for the rest of their expected and planned economic lifetime.

Maintenance does not stand alone as it used to years ago it is rather part of the integrated manufacturing processes and tangents to other processes are clear throughout the plan.

To be fully competent in the maintenance world, maintenance engineers must realize that managing maintenance means managing everything. Historically maintenance was the task that was performed by people on machines, in other words, where people intervened with machines, was seen as "maintenance". In today's high-technological world, it has become impossible to fully manage maintenance according to these old perceptions. Maintenance includes people, money, systems, customer requirements and machines and has clearly become a well-defined discipline or science.

Machines are nowadays designed with absolute accuracy and precision and designers are able to predict certain machine behavioural to such an extent that it is possible to predict failures and other irregularities long before it becomes evident.

Quality processes and programs rely on sound maintenance. Plant processes are built up of several sub-processes. In any of such processes machines are structured and designed to enable these processes to happen in other words, machines and their functions combined gives us various sub-processes. All the sub-processes combined give us our plant processes to a major or minor extent.

One of the most valuable assets in maintenance is our people. These are the energy that makes maintenance work or become reality. People must be developed to understand the science of maintenance as well as each maintenance process and how it coincides with other relative processes. People must be managed according to the disciplines inside the maintenance plan and processes and must be allowed to grow and develop in order to become more innovative. Since maintenance is a continuous process of improvement, the suggestions and designs will most likely come from the people participating in the maintenance process.

Money has a natural way of de-valuing and has become one of the scarcest items in the world. It is essential that while managing maintenance, that money and costs are known and engineers must understand the impact and growth of this resource, be it positive or negative. One must know what the impact on cost is when doing maintenance.

In today's world we live in an information environment and with maintenance this is no exception. For process or machine behaviour to become visible, and to predict or analyse the electronic media are used worldwide.

3. Abbreviations and terms used in this plan

"Kieppie" Parade – Cleaning of the plant after a shutdown

Discipline – Process controllers, Millwrights, Technicians, Welders, Fitters, Planners, etc.

ECP – Engineering change proposal, all changes must be logged accordingly

Equipment life cycle – The natural life cycle that equipment goes through during its planned economic life

Failures – Once a process or machine does not meet its required operating specifications

FFP – Fault finding procedures, procedures built from experience or hypothesis to guide maintainers in the event of faultfinding

FMEA – Failure mode effect analysis as per QS-9000

IRR – Internal rate of return, the rate at which an asset pay for itself expressed in time (month/year)

LRU – Line replaceable units, any spare that has been made Pokey Yokey and can be fitted without much adjustment.

Maintainer – Any individual or group of people of any discipline participating in any or partial maintenance processes or activities.

Pokey Yokey – Adjustments to eliminate the possibility of fitting spares wrongly

R&R – Repeatability and reproducibility

RCA/RCFA – Root cause (failure) analysis, the process of finding the root cause of failures

RCM – Reliability centred maintenance as per John Mowbray

ROI – Return on investment, the amount an asset contribute in creating wealth (profit) as %

Root cause – The cause of a failure that if corrected will prevent the failure from recurring

SD – Shutdown, a planned plant stoppage for some repair

SKS codes – The Columbus standard for numbering equipment

SOP – Standard operating procedures

SSST – Self-sufficient shift team, a team that consists of all the disciplines to be fully operative

WSI – Work standing instructions

4. The maintenance philosophy

The whole maintenance philosophy is based around the different stages that equipment goes through while in use, called the **lifecycle** of the equipment. Equipment needs different attention during different stages of its lifecycle.

Typical equipment lifecycle is as in Figure 3.1 below:

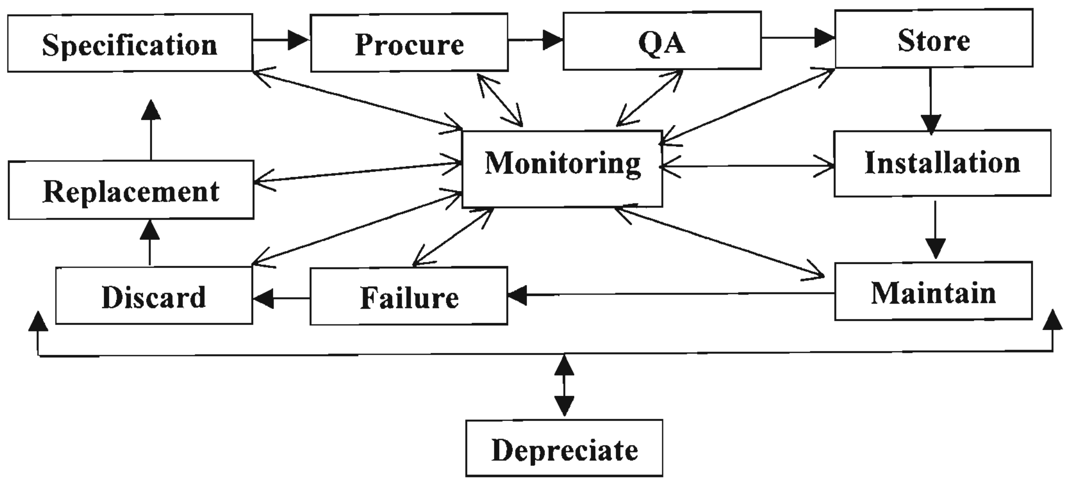


Figure 3.1: Typical equipment lifecycle

The following is a brief description of every phase:

4.1 Specification

This phase is usually after a need arises, or a deviation and/or gap is detected that leads to the specification of the equipment derived from the process or product needs. During this phase the complete operating, maintenance and functional specification is designed in order to fulfil the required need and function. This is the most important phase in the equipment's lifecycle and requires lots of energy and time. All involved disciplines and management levels evaluate the designs.

4.2 Procure

This means buying the asset or equipment. This phase involves putting out tenders for quotation, determining the spares needed for the maintenance function, and the screening of the various tenders. Capex designs are also done during this phase once the decision was made on the vendor and prices. IRR and ROI must be calculated and conform to CJV standards.

4.3 QA check program

Once the goods are delivered it must be inspected and checked against the required specifications and orders. Preliminary QA approval and acceptance are done. This phase is to make sure that the equipment or spares received adhere to the Hot Mill's quality standards.

4.4 Store

By using the supplier's recommendation and the RCM technique crucial spares must be identified. Applications to stores must be filled in, approved, and re-order levels must be clear. All queries from the store must be handled. The store phase can also be during the procure phase depending on the type of project.

4.5 Installation/Equipment exchange

Usually the installation phase starts with a project plan. This implies to all disciplines involved such as mechanical, electrical, instrumentation and production that will be actively assisting during the installation phase. The project plan can even be designed before the procurement phase but it is essential and dates, actions, etc. must be clear. All drawings must be designed, updated or re-draw during this phase and will follow the ECP route. This will consist of 3-sets of documentation for the plant, library and documentation centre – These can be an electronic copies or hard copies.

Once the physical installation is complete, the factory acceptance test will start. These tests must show that the assets are as per specification and need. After the factory acceptance test, the commissioning will start along with all the coding of every item. The Columbus SKS coding rules must be adhered to. Once the commissioning is complete, all the relevant drawings and other documents are in place and all the hardware coding is done, and the assets perform to the specification, the project is ready for production and must be signed over accordingly.

The necessary training, if any, as well as the monitoring techniques of this asset to ensure sound mistake proofing must be in place before the installation-cycle is complete.

4.6 Maintenance

Up till now, the prescribed schedules must be performed at the prescribed intervals as specified by the supplier. World best analysis practices on existing assets ensure a proper scheduled maintenance plan. Usually the maintenance phases of equipment or assets are the longest phases in the lifecycle. This is where we use various techniques and tools to "ensure that the assets fulfil its intended function, within specification". Note, once we want to improve on this, it becomes a "redesign" and is not seen as maintenance and is not the core purpose of maintenance.

Maintaining the asset implies to the following:
Daily inspections, cleaning of equipment, schedules and calibration. Line replaceable units or LRUs are also designed and kept to standard for quick changing of spares. To enable reliability, faultfinding procedures or FFPs must be designed and used when needed. The maintenance tasks and techniques will be discussed later in this document.

4.7 Failure

All equipment has the potential to fail. This phase has a direct adverse implication on the asset's reliability and should be minimized. Corrective action plans should be in place to either prevent a failure or to minimize the consequences of such a failure. Various tools and techniques exist and will be described later. The strategy for failure is clear, prevents it as far as humanly possible.

4.8 Discard of equipment

Once an asset has come to the end of its planned lifetime, and/or cannot perform according to the design specification, it becomes a hassle to use. Usually the cost of maintenance is very high and beyond economical reason.

During this phase the asset is discarded, or taken out of the production line and is replaced with new or better equipment (if needed).

Since the asset was part of the production process, it is treated as part of the business that creates money. If the asset was not depreciated during its lifetime is must be written off and taken from the inventory listing since this has tax and waste complications when ignored. Usually during this phase, a complete investigation must be done to understand why the asset did not perform in the first place (should it be before the end of the planned lifetime).

4.9 Replacement

Replacing an asset actually means the lifecycle of the new asset starts from the beginning and thus will all the above phases follow from the start (specification). The reason why the asset is replaced is usually clear and this is the base and paradigm of the new specification. It does not matter whether an asset is replaced at the end of its lifetime, or replaced because it could not meet the required specification. The equipment lifecycle starts again.

4.10 Monitoring

As can be seen from figure 3.1, all the equipment lifecycle phases needs to be monitored. This can be in various forms such as: project management, maintenance adherence, performance measures etc. and can be any media be it papers human or electronic systems.
In the Hot Mill we are using the electronic media to great success, but this will be discussed under the systems heading later in this document.

4.11 General

The philosophy of equipment lifecycle is more a system philosophy than a physical management program. This means that the systems must provide the necessary information about the equipment lifecycle although the accountable-maintainers must provide the system with data.

5. The Maintenance organisation

In order to conduct sound maintenance practices it is essential that a maintenance organisation be formed. This organisation is the combination of various teams that will assist in the maintenance practices. Teams must be aligned and geared as such that they are capable of conducting maintenance as needed.

5.1 The self-sufficient shift team (SSST)

In order to apply maintenance on a 24-hour basis it is necessary that maintainers are readily available. This concludes to the self-sufficient shift team. Each team consists of complete operations and maintenance teams reporting to one shift manager. The teams will conduct all maintenance activities on shift and are accountable for such. Every shift team has a designated area where planned maintenance is to be performed and running maintenance and breakdown management is conducted plant wide. The team typically consists of process controllers, fitters, welders, riggers, technicians' etc.

5.2 Long term maintenance technology support (MTS)

This team is a non-shift day-team that has a long-term focus on plant availability and new technology. Their accountabilities are plant-wide and as per need, partake in normal maintenance activities. This team will fully support the sift teams concerning projects, maintenance development and investigations.

5.3 Control and instrumentation (C&I)

This is a day-team that supports the shift-technician with process control and other maintenance tasks. The day-technician focus on long-term related issues and their accountabilities are plant-wide and per need. This team will fully support the shift teams concerning projects, maintenance development and investigations.

5.4 Process control and development (PC&D) teams

The PC&D teams do not focus on plant maintenance and thus will not be discussed in this plan.

6. Various types of maintenance

The equipment lifecycle is divided into 3 types of maintenance namely, planned maintenance, running maintenance and breakdown management. In essence people will only maintain machines under these three headings although the complete lifecycle management takes place.

6.1 Planned maintenance

These maintenance tasks will be performed in each designated shift-area. A process FMEA might trigger the whole process and includes processes such as; critical equipment identification, RCM analysis and maintenance planning. From maintenance planning, processes such as maintenance schedules optimal change-out, premature failures, SOPs, training, refurbishment and log- and short term planning evolves. Risk analysis and equipment lifecycle management is also part of planned maintenance.

6.2 Running maintenance

These maintenance tasks will be performed by the shifts over the whole plant. Running maintenance tasks are shift-to-shift tasks and might or might not evolve from planned maintenance. Processes such as lubrication, RCM II-inspections, and equipment cleaning, SEC, MMI alarm handling and calibration procedures all fall into the running maintenance processes. These processes are critical for maintenance since this must be performed while the plant is productive.

6.2.1 Whole plant

These activities usually are the day-to-day activities that take place and are performed over the complete plant. Usually these tasks include the prevention of the three evils namely dirt, lack of lubrication and equipment abuse.

6.2.2 Lubrication schedules

Lubrication is the most important maintenance task to be performed during running maintenance. These schedules must be specially designed to ensure all equipment that needs lubrication must be lubricated with the correct type of lubrication, the right amount at with the correct intervals. This is the corner stone for sound lubrication scheduling and must be adhered to. Theoretically no equipment should fail due to a lack of lubrication. The maintainer must ensure that there are absolutely no problems in this area. Lubrication also spread to the filters in the systems, all the bulk-tanks to be in good condition and systems to be leak-free. This applies to all oil and grease lubrications. Since most lubricants are flammable, extreme care must be taken in this regard.

6.2.3 Inspections and RCM routes

Human inspections are the cornerstone for a sound preventive maintenance program. It is essential that maintainers get the "feel" for the plant. The only possible manner to do so is to regularly visual inspect the equipment. This task reaches far beyond just inspection maintainers must capture information about their machines. All identified crucial machines must have a complete inspection sheet that will lead the maintainer through basic root steps when inspecting the machine. The sheet must be ticked off and after inspection handed in with the planner. All irregularities must be noticed and action steps must be taken to prevent possible failures. All the information on the sheet must be preserved for future analysis should it be needed.

In the Hot Mill we've designed an extra process to the RCM II analysis. We try and combine inspections on a specific route so that less energy is necessary to do the inspections. Typically one maintainer can cover a complete route thus investigating all the equipment on the route. This implies that the inspection schedules must be designed as such a way to tell the maintainer when a specific condition (inspection point) is within specification and when it is a deviation from the specification, as well as to what he must do to correct the deviation.

6.2.4 Equipment cleaning

This process is also part of the corner stones of maintenance. Clean equipment lends to good working environments and proud maintainers. For maintenance clean equipment is more efficient faultfinding and possibility to spot deterioration and other deviations such as cracks. Debris around and in machines causes unnecessary friction and damage to seals and other soft materials and spares.

All optical equipment such as cameras, pyrometers and hot metal detectors will remain clean at all times. The maintainers must ensure these critical devices to be in sound condition at all times.

All measuring equipment shall remain clean as far as humanly possible. This also applies to all hand-held equipment and not just equipment in the processes. Cleaning schedules will not be neglected and all the necessary legislation must be adhered to.

6.2.5 Statistical Equipment control (SPC)

Just as it is possible to analyse our processes statistically (SPC) it is also possible to analyse equipment statistically. All the identified equipment is measured and the real-time information is stored on a database. This stored data must be mined and put together to analyse the equipment behaviour to see deviations that might not now have a big adverse effect on production but could have in future. "What can happen will happen!" The whole principle is that once the crucial equipment is identified, through various processes, that the maintainer found some way of measuring the equipment be it electronically or manual. All the data captured with SPC must be preserved and the integrity of the information must be high to ensure good information and sound analysis.

6.2.6 MMI alarm handling

The shift-maintainers must handle all alarms as they appear on the MMIs. Recurring alarms must be investigated and root causes for the alarms must be eliminated. No alarm-buildup must be allowed and reactions must be swift.

6.3 Breakdown management

Handling breakdowns are not seen as maintenance but rather as special cases where energy must be put into finding root causes and problems. Breakdown management will be conducted throughout the complete plant by all maintainers.

The fix controls you, you do not control the fix. The basic strategy is totally reactive. When things break, we fix them. These types of tasks are very expensive and uncontrolled but are not part of official maintenance. This leads to the "failure dilemma" where maintainers are unable to predict failures to machines and pro-active tasks are thus not identified. No matter how good we know machines behaviour, the dilemma will always be there that equipment can break.

The whole paradigm should be to understand the consequences of such failures and approach defects from this angle. This is the area where perseverance of failure data is crucial in order to build a strong knowledge database that can be used to do future analysis and investigations.

6.3.1 Functional failures

The crucial machines/processes must be identified in the FMEA process and tags must be monitored to identify the possible cause of failure. The system must know which machine failed to deliver its primary functions within specification. This can be done manually or at a later stage automatically.

6.3.2 FFP trigger

A pre-designed FFP must now be generated to assist the maintainer to find the fault and rectify it as soon as possible. Should the FFP identify the root cause of the failure actions must be taken to eliminate the cause and thus prevent it from happening again. Maintainers must also analyse relative equipment and products that might be influenced by the current failure.

6.3.3 Equipment impact studies

An investigation must be done to identify whether surrounding equipment was not damaged due to the current failure. A list of all the possible equipment must be made and each must be monitored and inspected to ensure that the surrounding equipment is sound and not affected. All tasks carried out must be logged against the relative equipment and the data must be preserved.

6.3.4 Product impact studies

An investigation must be done to identify all possible product defects and normal NCR rules must be applied. Backward inspections must be done to ensure that all the products rolled since the last known standard are all within specification. All investigations carried out on equipment must be logged against the relative MPOs and all data must be preserved.

6.3.5 Decision model

The decision must now be made about whether the plant must be stopped and the problem fixed or whether we should continue rolling and fix the problem later. If the impact studies reveal that the failure is severe and the plant is down it must be fixed. The rest of the criteria are from crucial to less crucial, safety, quality, customer, cost and spares. The model should guide the maintainer as to under which criteria he should stop the plant and resolve the problem or resolve it later.

6.3.6 Gathering of failure data

These actions are the cornerstones in the event where sound root cause analyses is to be done. Gathering failure information will not take more than

10 - 15 minutes if a structured approach is followed however relevant data should not be neglected.

1st – the approach should be that of a reliability detective, all the information about the breakdown should be carefully examined, and the **real** root cause should be identified.

2nd – the plant should be prepared for production "AFTER" the necessary information was collected. Production always has the highest priority, in the case of a breakdown; gathering information should be the paradigm that drives the scene.

3rd – The gathered information must be examined and the root cause for the specific failure should be identified. Plans must be made to cure the root cause thus preventing this particular failure from happening because of this root cause.

4th – The plan must be implemented as soon as possible and deadlines must be met. Records must be kept and the conditions should be closely monitored until satisfied that the real root cause was addressed.

6.3.7 What information should be gathered to solve root causes?

In short everything that will help! In general the information is categorised into 5 groups. It is called the "5P's" since all of them starts with the letter "P".

*** PARTS ⇒**

Note all the parts of the breakdown. Should it be possible, collect the parts and tag them. Where this is not possible, take photographs that clearly show the defective parts.

*** POSITION ⇒**

This is information concerning the positions of everything related to the breakdown, look at valves, cylinders, process-related movements like side-guides etc. Also note the correct positions not only the wrong!

*** PAPER ⇒**

This information is about all the paper-related information concerning the breakdown. This includes the operating specification of the process, SPC alarms, and event and alarm printouts and where possible, recordings while the problem occurred, utilize the level 1 server.

The first 3 "P's" are the most important ones since this information is destroyed when the plant is back in production.

*** PEOPLE ⇒**

This information is collected from the "eye witnesses", usually the process controllers saw the problem and they should be the 1st to be questioned. Note everything as described by them before, during and after the occurrence. If possible this questioning can be audio recording. A questioning form will be designed.

*** PARADIGM ⇒**

This information will tell you what people usually accept as the standard. This also means talking to people and get their perspective of the problem since this can reveal valuable information in solving the root cause.

Doing the RCFA (root cause failure analysis):

Once all the information from the "5P's" is collected and further investigation is necessary, the RCFA can start. By carefully examine all the information and keep on asking "why" the root cause should reveal itself. Should more information be required then it should be gathered. Many root causes will reveal itself by only collecting the necessary information. All the data collected must be preserved for later analysis or RCFA.

Reliability detectives

Every team should have one (1) person per "P". Thus when a breakdown occurred this person should collect the information for the "P" he is responsible for as quickly as possible. With SPC and other systems fully in place, collecting the necessary information should take about 10 –15 minutes. Only after all the information is gathered, can the plant be prepared for startup and production can continue.

6.3.8 Breakdown recovery

All the activities needed to get the plant in production must now be done, this includes spares management, FFPs and other procedures and specialist assistance. Since the plant will be of for a pre-identified time, the off time must be fully utilized thus other maintainers not participating in the breakdown recovery must do work from the outstanding work lists that can be completed within the given time. The plant must be restarted according to the existing procedures and FFPs and other documentation must be updated.

6.3.9 Premature failures

Should a failure occur it must be determined weather this failure was premature. It must be evident that the equipment/process failed before it's planned failure-time. Should the failure be after the planned failure time it is seen as optimal change-out and the new spares, procedures and LRUs should be readily available. All failures must be logged and analysis must be done on pre-mature failures.

7. How will people do equipment maintenance?

For any maintainer, to participate in the maintenance processes, must understand the processes. Apart from this training on the modules attached to this plan, he also needs to do some additional training. The proposed training will be the same with a few adjustments and add-ons. Although some sections (PC&D) don't do direct maintenance they still have some responsibility towards the SSST regarding maintenance on shift. This also applies to the long-term teams and other resources not on shift as well. In the next table 3.1 these accountabilities for tasks will be clearly shown:

Number	Responsibilities	Self sufficient shift	Level 2	PC&D	Daily maintenance	Process engineers
1	Manuals -					
	Location	X				
	Quality of manuals	X				
	Maintenance of manuals	X			X	
	Operating of manuals	X				
2	Training module	X				
3	RCM II Analysis	X		X	X	
4	Spares listing	X			X	
5	FFP's	X			X	X
6	Initial LRU designs				X	
7	LRU's, listing & location	X				
8	Vendor's / supplier list	X			X	
9	Equipment contingency				X	
10	Redundancy levels		X	X	X	
11	Process contingency	X		X		
12	Proper calibration QS 9000	X				
13	Improvements & suggestions	X		X	X	X
14	Inspections & schedules	X				
15	Quality verification	X				X
16	Maintenance history	X		X	X	
17	Condition monitoring	X				X
18	Equipment training & systems	X		X	X	
19	Electronic alarming & E-mail				X	
20	SPC analysis and management	X		X	X	
21	Equipment trends				X	X
22	Equipment redundancy			X	X	
23	Y2K compliance				X	
24	Failure management					
	- RCFA	X			X	X
	- Failure history	X			X	X
	- FMEA	X			X	X
25	Improvement suggestions	X	X	X	X	X

Table 3.1: Accountabilities for tasks

Since most of the maintenance (all types) will be performed on the 24-hour shift, it is essential for the day shifts to assist these teams as in the table above.

7.1Combining human resources and equipment lifecycle

7.1.1 Specification

Tasks	Equipment Team	Shift manager	Team manager	Technicians	Planner	Artisans	Millwright	OEM	Specialist
Deviations			X	X					
Options investigations/Type								X	X
Needs/GAP analysis			X	X					X
Write specifications									X
Design- RCM, FFP, LRU									X
Evaluate designs			X	X					
Evaluate written specification			X	X					X
Integrate configuration /projects			X	X					X

Table 3.2: Combining human resources and equipment Lifecycle for Specification

7.1.2 Procure

Tasks	Projects	Shift manager	Team manager	Technicians	Planner	Artisans	Commercial	OEM	Specialist
Tenders for quotations	X				X		X		X
Vendor sifting	X	X	X		X		X		X
Capex spares & tools	X		X	X					X
IRR analysis	X								X
Buying	X						X		
Warranty clarifications	X	X						X	X

Table 3.3: Combining human resources and equipment Lifecycle for Procurement

7.1.3 QA check program

Tasks	QA Department	Shift manager	Team manager	Technicians	Planner	Projects	CES	OEM	Stores	Specialist
Management program	X	X								X
Goods inspection/ receive			X	X			X			X
Compare to specifications			X	X			X		X	X
QA approval store – Visual									X	
Pre-QA sing-off / Tested		X								
Goods Inspect - Manufacture	X						X			X

Table 3.4: Combining human resources and equipment Lifecycle for QA program

7.1.4 Store

Tasks	Stores	Shift manager	Team manager	Technicians	Planner	Artisans	Millwright	OEM	Specialist
Identify crucial spares			X					X	
Stock applications			X	X					X
Application approvals									
Re-order levels			X	X					
Store query management			X	X					
Goods delivery					X				

Table 3.5: Combining human resources and equipment Lifecycle for Store

7.1.5 Installation

Tasks	Project leader	Shift manager	Team manager	Technicians	Planner	Artisans	Millwright	Process controller	Specialist
SKS coding	X								
Project plan design	X		X		X				
ECP & drawings	X								
Physical installation	X								
Test against specification	X								
Audit to specification	X		X	X					
Commissioning	X		X	X					X
Redundancy FFP, SOP		X							
Sign over for production	X								
SPC Implementation									X
Equipment training		X		X					
Review LRU specifications				X	X				

<u>Table 3.6: Combining human resources and equipment Lifecycle for Installation</u>

7.1.6 Maintenance

Tasks		Shift manager	Team manager	Technicians	Planner	Artisans	Millwright	Process controller	Specialist
Scheduled maintenance		X							
History feedback (L1 server)			X						
Cleaning				X					
Inspections				X		X	X	X	
Calibrations				X		X	X	X	
FFP's				X				X	X
Design LRU's				X					X
Re-engineering/upgrades									X
New technology									X
Redundancy		X							X
Safe operating procedures		X	X	X		X	X	X	X
Big 5 concept		X	X	X		X	X	X	X
RCFA			X	X					
1st Line Maintenance training			X						
Equipment training			X	X					

1st line maintenance						X	X	X	
Maintenance planning		X	X	X	X				

Table 3.7: Combining human resources and equipment Lifecycle for Maintenance

7.1.7 Failures

Tasks		Shift manager	Team manager	Technicians	Planner	Artisans	Millwright	Process controller	Specialist
Failure information (RCFA)				X		X	X	X	
Failure investigations – FFP's			X	X					
Root cause failure analysis			X	X					
History information indicator				X		X	X	X	X
Long term corrective action		X	X						X
Short term corrective action			X	X					
Correction verification			X						X
Breakdown recovery		X							

Table 3.8: Combining human resources and equipment Lifecycle for Failures

7.2 Enabling people to manage the equipment they are accountable for

Every shift manager must divide his responsible plant into areas and allocate these areas to specific groups or persons. The division and allocation is totally at the discretion of the shift manager and how he sees fit. The final plan must be documented in order for him to control and manage the maintenance of his responsible equipment. The primary aim of the accountable groups/persons is to prevent the three evils namely: abuse, dirt and lack of lubrication. Every group will maintain their machines as per scheduled maintenance. Every machine will have an inspection sheet that will enable them to do proper inspection.

7.3 Managing Shutdowns in the rolling mills

7.3.1 Planning the shutdown

Complete shutdown work lists must be available, these must indicate:

- Describe all the SD work
- Spares and other resources internal and external needed
- Availability of spares and resource allocation
- Time chart c/w critical path and priorities
- Categorize work in:
  - Preventive maintenance
  - Predictive maintenance
  - Improvements
  - Re-engineering
- All SD schedules
- SD-start & stop times

7.3.2 Preparing for the SD

- Preliminary SD meeting
  - This meeting is held to go through the SD lists and analyze to find possible deviations and logistic problems. Extra planning is needed for these deviations. The shutdown coordinator and senior planner can form the detailed SD plan from information gathered in meetings. Certain planned shutdown work might come off the list. The success of the SD purely depends on the planning thereof.
- SD detail meeting
  - All the involved disciplines to attend this meeting where the SD manager gives the detail shutdown plan feedback.
  - This will include everything c/w all the remaining tasks.
  - Involved disciplines to give feedback on each item on agenda concerning spares and resources, this include production stoppage and time of shutdown start-up.

7.3.3 Managing the shutdown

- The production manager will coordinate the complete shutdown.
- The senior planners along with each section planner will be responsible for:
  - Up to date bar charts at each section and the overall SD chart
  - Quality control
  - Contingencies
  - Reports on deviations from plan
- The relative team managers will feed all the information from the floor to the planners for updating of the SD system and communication to management.
- Area safety officers are visible throughout the SD for safety assistance where needed.
- All SD work to be done according to chart times.

7.3.4 Starting up of plant after SD

- Various sections to report finished jobs
- Various sections to report finished sections in plant
- Millwright to declare "switch-on mode" and follow start-up procedures
- After start-up checks to be performed by all disciplines in area
- Quality checks are compulsory
- "Kieppie" parade by all to ensure dirt and debris to be removed from the plant
- Responsible team manager to declare "section alive" once fully switched on
- Dummy bar tests every 30 minutes to test dynamical plant operations
- All start-ups preferably during normal daytime.

8. Key-9 and the maintenance plan

Although this plan does not describe the Key-9 (one f he keys from the 20 keys improvement program) concepts directly, this section shows that Key-9 is part and partial included in this plan. By supporting this strategy Key-9 will be implemented but with much more weight than explained in the TWI files.

8.1 Dividing the plant in accountable areas:

This step is crucial to implementation of the plan. Every person or group must know which area is his accountability concerning maintenance of equipment. Start with the most problematic and crucial equipment in your plant.

8.2 Initial cleaning:

Every area must be cleaned and kept that way. Reasons for dirt must be eliminated. Daily inspections must be conducted on the assigned equipment.

8.3 Implementation of easy excess to areas difficult to reach:

Where it is difficult to reach areas to clean, methods or other ways must be installed to clean everywhere providing that the root causes for dirt are eliminated.

8.4 Asking "why" five times

The strategy to teach people to keep on asking "why?" something failed a few times until the real reason for the failure is evident is nothing else than "root cause failure analysis". The shift will still use this strategy when solving problems, RCFA will be an official analysis conducted by an RCF-analyst with a multidiscipline team. The latter will most likely take place off-shift.

8.5 Inspection sheets, documentation & spares:

All the necessary documentation must be collected and stored in the designated areas. Plant spares must be close-by and the inspection sheets must be used. This sheet must be kept for history and trends. SOP's, LRU's and FFP's must be easy and fast to acquire and easy to use. The shift manager must monitor these maintenance activities closely and react to deviations from standards. A system will be developed to capture inspection sheet information electronically.

9. Statistical Process control SPC

SPC is a method used to determine whether or not a specific process operates stable within its required parameters. In general, data is gathered and "Westinghouse" rules are applied to detect if such a process becomes unstable or out of specification. SPC can be done with manually but various software packages are obtainable that will do electronic analysis with alarms etc. In the maintenance environment, which focuses more on equipment the SPC concepts can be applied to machines and sub-processes. This term is called SEC (statistical equipment control).
According to the RCM II concepts all equipment fails with to a well-defined P-F (problem to failure) curve. Ideally would be to detect the problem area that is, depending on the type of failure, long before the failure point. To do this, equipment movements must be monitored and the operating specifications must be well defined. To make this P-F area visible, SPC is used but only on equipment level. Such SPC can be electronically or manual where the latter can be conditional- or time-based.

Monitoring equipment movements and conditions allow us to detect linear patterns that will predict future behaviour such as problem points, R&R etc. Doing this electronically will require a real-time logging of data machine but will lessen the time searching for problems.

10. Capturing maintenance information

To enable any person to manage maintenance means that such a person has visibility and develops a "feeling" for processes and the success thereof. This becomes impossible to manage with a paper system and thus electronic media will be much more efficient.

In short – all maintenance data must be logged to a specific system. The system must give the ability to analyse historical information and use such analysis for sound decision-making and management. The system will grow with the maintenance activities thus building a sound information platform for the future. This will enable maintainers to "zoom" in on problem areas and proactively react to such before it reaches disastrous measures. Ideally the system must be on a corporate level to enable Columbus to gain the benefits of sound world-class maintenance practices.

11. The 5-golden rules of maintenance

11.1 PLANNING

Pro-actively plan to succeed then follow the plan.

The above rule describes the following criteria:

- Plan twice and execute once – This implies that proper sound planning must tale place.
- Resource utilization – Optimal and cost effective planning and usage of all maintenance resources.
- Schedule adherence – Adhere to all schedules generated and designed within the manufacturing system.
- Pro-active – Plan all tasks to be in a pro-active manner.
- Cost efficiency – Apply money-resources only where it is cost efficient to do so.

11.2 KNOWLEDGE

Learn, preserve, share and apply, customer needs and equipment knowledge

- The above rule describes the following criteria:
- Learning – To be able to always learn from past experience and information.
- Sharing – To share all knowledge to every person in need thereof.
- Preservation – To preserve knowledge and experience for future usage.
- Visibility – To allow any partaking individual to be able to use our knowledge bank.

- Process, product and equipment – Focus will be wider and more innovative.

11.3 PEOPLE

Take ownership and support our customer with disciplined teamwork

- The above rule describes the following criteria:
- Teamwork – Our strength lies in one team complete with each member's support and inputs. No individual is bigger than the team.
- Support our customer – To provide excellent maintenance services to all customers and exceed their expectations.
- Ownership – Each team maintainer will take full ownership of the quality of his service offered, equipment maintained, scheduling and training.
- Don't compromise – Maintainers will always follow the procedural routes and make sure to improve such to be optimal efficient. This includes being first time right and procedural correct.
- Discipline – Maintainers will act according to disciplined intentions such as equipment care as if it was our own, keep equipment clean, at all times pro-active elimination of the three evils (dirt, lack of lubrication and abuse), constantly ensures that loops are closed complete with feedback, preservation of information and inspections.
- Motivated workforce – Maintainers will maintain with passion, commitment and as a team always promote motivation of fellow team members.

11.4 STRATEGY

Lifecycle management for optimal life

The above rule describes the following criteria:

- Flexibility – Allow people, procedures and processes to adopt to all changing criteria within the Columbus guidelines.

- Design for excellence – Start with the end in mind, only contributing to bottom line figures really counts.
- Continuous improvement – To always seek the better solution of doing everything and to continuously do this as a way of life.
- Best technology – Continually seek the best-proven technology and when required develop own technology to ensure Columbus to be a world leader.
- Root cause focus – Eliminating all recurring problems. Continuously studying failures and apply skilled analysis for prevention of breakdowns and eventually total elimination thereof.
- Lifecycle management – To manage every aspect of an asset, program or process's lifecycle during it's planned intended life.
- Innovation – People's knowledge must be grown in process, equipment and customer-needs to allow them to be innovative.
- Safety - All maintenance tasks, designs and actions will be in accordance with the safety-legislation and will be done accordingly.
- Risk management – All high-risk aspects will be driven down to an acceptable, manageable level. All risks will be evident in both safety and costs management.

11.5 SYSTEMS

Providing the right information, at the right time, in the right place and format, to support decision-making

The above rule describes the following criteria:

- Systemizing knowledge – Capturing of knowledge on all machines to enable others to use and learn.
- Decision support – To give the relevant information that will enable maintainers to make the correct, most effective decisions within limited time.
- Information availability – To supply the relevant information as well as capturing of data. To ensure systems are up and running and NOT

causing any QCDSH (quality, cost, delivery, safety, health) deviation or downtime.

- Visibility – Interaction to the system available anywhere on the plant floor.
- Data integrity – Capturing the correct relevant data at the correct time. No unwanted information in the system.
- Analysis – The ability to analyse data to ensure sound information delivery without much filtering of data. To be able to do linear and non-linear analysis of relational information.
- Integrated support – Has transparent support to any tools needed to integrate with this system.
- Measurement – Real time data-logging where needed with statistical process control applying Westinghouse rules and alarming.

11.6 Implementation of the plan

The following aspects were seen as important points that must be noticed for implementation.

11.6.1 QS-9000 prerequisite

Since the maintenance plan support QS-9000 and is dependent on process-FMEAs to trigger some of the maintenance processes, the FMEAs must be in place to ensure that the RPN numbers are clear.

11.6.2 Basic building blocks.

The basic building blocks around which the plan was designed must be well defined and put in place first in order for the plan to succeed.

11.6.3 Detail per maintenance discipline.

The detail actions for every discipline partaking in the maintenance activities must be clearly understood and sorted out.

11.6.4 Detail actions to be developed including the correct sequence of each.

The detail of every block in the processes must be clear with respect to whom will be doing what where and when.

11.6.5 Standard based training on the plan.

To ensure unity paradigm with the team managers and planners of both production and maintenance throughout the rolling mills, this plan as presented to the managers will be presented to all team managers and planners. Their inputs will be investigated and applied where applicable.

11.6.6 Goal alignment.

All partaking teams will be put through a goal alignment on the 5-golden rules of maintenance. This will however, only be to the team manager's level and not the complete team.

11.6.7 Total shift team workshop.

The complete shift team will go through a more detailed workshop to ensure that the alignment is reached on the maintenance proposal.

3.4 Steelplant Maintenance Plan (SPMP)

The Steelplant has no documented maintenance plan. However, the CSCMS was given to the maintenance engineer at the time of writing, at the Steelplant, Andries Opperman, who compared the current practices at the Steelplant against the CSCMS. This will be discussed in the evaluation of the maintenance strategy in chapter four.

3.5 Chapter Summary

The Columbus Stainless Corporate Maintenance Strategy (CSCMS) as well as the Hotmill Maintenance Plan (HMMP) was presented in this chapter. The CSCMS stipulates that cost effective maintenance, optimal equipment functionality and process control can be achieved by:

- Applying a *reliability centred maintenance* philosophy.

- Utilising *spares management* techniques.
- Continuous *measurement and control of equipment and processes*.
- Equipment *life cycle management*.
- Ensuring effective usage of *information*.
- Utilising *1st line maintenance* principles.
- Utilising *self-sufficient teams*.
- *Developing people* through coordinated maintenance *training* programs.
- Ensuring *continuous improvement* through best practice techniques and by fostering a *learning culture*.
- Incorporating *QS9000* principles.

According to the CSCMS, quality planning results in quality maintenance, which results in quality products, to exceed customer requirements. In order to achieve this the CSCMS details how the following can be carried out:

- Maintenance Management Planning.
- Asset care/strategy implemented aids.
- Maintenance effectiveness optimisation.
- Maintenance support services.
- Safety, Health, Environment and Quality.

According to the HMMP, the whole maintenance philosophy is based around the different stages that equipment goes through while in use, called the lifecycle of the equipment. The following strategies regarding equipment maintenance is also detailed:

- Planned Maintenance;
- Running Maintenance – maintenance tasks performed by the shifts over the whole plant; and
- Breakdown Management.

The evaluation of the CSCMS and the maintenance plans for the Hotmill and the Steelplant will be presented in the next chapter.

Chapter Four – Evaluating the Corporate Maintenance Strategy and the Plant-specific Maintenance Strategies

4.1 Introduction

This chapter evaluates the Columbus Stainless Corporate Maintenance Strategy described in chapter 3 against the grounded theory presented in chapter 2. The Plant-Specific maintenance strategies described in chapter 3 are also evaluated against the Corporate Maintenance Strategy to see if they support this strategy.

This evaluation process consists of identifying maintenance practices contained in the CSCMS and comparing it to the grounded theory in chapter 2. A gap analysis is conducted in this manner between World Class/Best Practices maintenance philosophies and the CSCMS. The maintenance practices as contained in the Plant-Specific maintenance strategies are also compared to the CSCMS, which will give an indication of gaps between World Class/Best Practices maintenance philosophies and the Plant-Specific maintenance strategies, and between the CSCMS and Plant-specific maintenance practices. This process is part of the methodology, which was based on the construct developed in figure 1.2. The evaluation of the plant-specific maintenance strategies will be discussed under the same headings as the CSCMS evaluation. This plant-specific evaluation will reflect just a discussion on evidence/no evidence of a gap, and will exclude the discussion on the grounded theory on the relevant maintenance practice. The discussion on the grounded theory on the relevant maintenance practice will be included in the evaluation of the CSCMS.

A Maintenance management maturity assessment by means of a questionnaire is also included to target the plant personnel at the two plants. However, before the evaluation of the different maintenance strategies and the maintenance management maturity, the vision and mission of the organisation is evaluated, as these are basic direction-setting tasks that map out where the organisation is headed, and upon which strategy is developed.

4.2 Evaluation of the Vision Statement

The vision statement of Columbus Stainless is very short and direct. It reflects management's aspirations for the organisation and its business. This strategic vision provides a panoramic view of "where we are going", giving specifics, about the organisation's future business plans. Although this is not directly apparent, one has to define "becoming the best operation" in terms of every organisational activity (Human Resources, Finance, Sales and Marketing, Information Systems, Operations, Maintenance, etc) involved with producing stainless steel.

4.3 Evaluation of the Mission Statement

The mission statement describes Columbus's present business scope ("who we are and what we do"). This mission statement defines the business in terms of what to satisfy, whom to satisfy, and how to produce the satisfaction:

- *What is being satisfied?* Customer needs in the forms of quality stainless steel.
- *Who is being satisfied?* Customer groups that includes customers all over the world with particular emphasis on stainless steel users, and all new customers that can "add stainless steel to their life" – utilising stainless steel to meet their goals and objectives.
- *How to produce satisfaction?* Columbus's activities, technologies, and competencies in creating and delivering value to customers and satisfying their needs, are depicted by the emphasis on "quality". It is Columbus's intention to produce only the best quality stainless steel. By adopting this mission into a maintenance strategy process, all maintenance activities can be directed in order to meet all quality standards in every value-adding activity.

4.4 Evaluation of the Corporate Maintenance Strategy

4.4.1 Scope and Purpose – Leadership and Policy Development

Against the backdrop of the evaluation of the vision and mission statements above, the corporate maintenance strategy reveals this support very distinctly in its scope and purpose. The emphasis is on "Maintenance applicable throughout Columbus Stainless, to all machinery, plant and processes that directly affect product quality, and the safety and health of personnel" and "with acceptable levels of reliability, availability and safety, at cost levels as specified within the overall Business Plan." This scope and purpose satisfies one of the World Class maintenance practice mentioned in the grounded theory in chapter 2 – *Leadership and Policy Development*. However, there are no vision and mission statements that support Columbus Stainless's directions and goals in this Maintenance Strategy.

4.4.2 Maintenance Organisation

According to grounded theory on achieving a World Class Organisation, *Organisational Structure*, is listed as one of the areas of where maintenance organisations function at three major levels: organisational level (functional and structural relationships), process level (work activities), and job performer level (individual worker). The ineffectiveness of one level could negatively impact another level. The CSCMS spells out that the organisational structure supports the current Business Plan and Drivers, and that the formal structure exists with plant maintenance as part of operations department per plant area. Also the CSCMS states that a standardised structure down to maintainer level is available and should be implemented.

4.4.3 Maintenance corporate policy

RCM: The CSCMS postulates that RCM philosophy should be applied to all plants. As mentioned in chapter 2, RCM is a "best-practice" maintenance methodology, and this means that the CSCMS is aligned with "best-practice" maintenance practices. This means that the focus on the actual potential failures and why they should be suppressed, which is the basis of RCM, is exercised and driven.

Spares Management/Inventory Control: The spares management techniques details exactly how this critical input in the maintenance mix should be carried out. According to the grounded theory in chapter 2, the only reason for keeping a stock of spares is "to avoid or reduce the consequences of failure". The CSCMS echoes this by stipulating, "Effective spares management techniques are in place to reduce downtime risk, drive plant availability and reduce costs."

Also, the CSCMS adopts the Reliability Centred Spares (RCS) technique as a business standard for optimal spares holding, which is in keeping with grounded theory on World Class Maintenance Practice on *Inventory Control*. The purpose of this area is to refine the maintenance stores and acquisition process to streamline parts appropriation – focused on the right parts in the right place at the right time. This would involve standardised stores and inventory practices, to improve the process of requested parts to reduce wasted effort and inactivity.

Measurement and control of equipment and processes: The CSCMS stipulates seven points on continuous analysis, measurement and control. These points support maintenance theory on FMEA and RCFA as discussed in chapter 2.

Lifecycle Management: The CSCMS also consists of practicing equipment lifecycle management. There is no gap here as grounded theory suggests that lifecycle management involves management of the three approaches of maintenance – RTB, PM and CBM. The CSCMS details condition monitoring techniques, with a continuous move towards CBM and on-line condition monitoring. Besides applying RCM principles which deal with various maintenance practices throughout the equipment lifecycle, the CSCMS postulates that each equipment unit has a unique maintenance plan, and has as part of its maintenance plan development of the following strategies:

- Scheduled maintenance (preventative)
- Condition based maintenance (predictive)
- Time based maintenance (overhaul, replace)
- Breakdown maintenance (corrective)
- Design-out maintenance.

The CSCMS also includes benchmark indices for planned maintenance.

The CSCMS details lifecycle management intensely, in that it states categorically that systems must be aligned with business processes in order to fulfil equipment lifecycle studies, dedicated teams should be available for lifecycle analysis, and guidelines must be available for reference purposes.

Information: Grounded theory suggests that Best Practice maintenance is established, with fully integrated information systems, and users performing maintenance administration. The CSCMS fully supports this practice by detailing the usage of maintenance information. These details include amongst others, allowance for effective management decisions, training of all users of information, integration of new information systems to existing systems in line with the CSCMS, and security access structures for protection of sensitive information.

World Class Maintenance theory also suggests that most maintenance activities, especially *Planning and Work Control*, and successful maintenance practices depend a great deal on a robust information system having a robust *CMMS* program. The CSCMS supports this by stating that RCM analysis results be integrated with the CMMS, that the CMMS must be in operation and available to all maintainers via personal computers and/or walk-in centres, and the system must be flexible for customisation, in line with optimised business rules.

1st Line Maintenance: The theory on TPM in chapter 2 suggests that an organisation must achieve autonomous maintenance. This increases the involvement and flexibility of use of the operators or users from a passive involvement in maintenance to one in which they will carry out minor setting, maintenance and lubrication activities to keep their equipment in good condition. The CSCMS has included this maintenance philosophy by detailing principles such as training for production personnel to perform 1st line maintenance tasks, e.g. the elimination of the three maintenance evils – abuse/misuse, dirt and lack of lubrication.

Grounded theory on autonomous maintenance suggests that "the goal of involvement is to free up some of the maintenance resources so that they can be deployed in activities requiring higher levels of technical skills, such as predictive maintenance or root cause analysis." The CSCMS fully supports this by suggesting that in order to free the maintainer to perform more complex and critical maintenance tasks, the 1st line maintainer must be empowered to accept responsibility and be accountable, and the plant-specific 1st line maintenance tasks, required tools, and work instructions must be specified.

Developing People and Training: Figure 2.7 depicts very clearly that "people development" is one of the maintenance policy sectors to be included in a maintenance strategy. One of the five pillars of TPM is *Maintenance Mindset and Training*. A heavy emphasis is placed here on appropriate and continuous training for both maintenance and operating staff to have all the skills to carry out their roles. This means maintenance training, operations training, leadership training, training about root cause analysis of the major losses, reliability training, etc. Grounded theory on training also states that training should be provided in line with the development needs for the individual, in line with the future maintenance strategy, and a training programme can be structured to give:

- Improved skill levels in the existing core disciplines – to include new aspects of technology where appropriate.

- Improved familiarity with other trades whilst maintaining major involvement in the core trade.
- Improved plant and process knowledge in improved diagnostic skills.
- Improved initiative and self-motivation in designing-out maintenance.

The CSCMS has formulated all the major maintenance related training courses that are available to all relevant personnel in line with a maintenance role skills matrix. This training incorporates the above view of the grounded theory.

Also, as part of its continuous improvement techniques, the CSCMS states that there should be a continuous drive for people upliftment, succession career planning should be in place, and relevant knowledge should be systemised.

Continuous Improvement: According to theory, this principle is supported greatly by "Kaizen" and TQM philosophies. Grounded theory also states that effective use of TQM/continuous improvement techniques is a valuable asset in a company's portfolio – one that can produce important competitive capabilities (in product design, improved efficiency, cycle time, lower cost, better product quality and reliability, service, and greater customer satisfaction) and is an important tool on how to execute a strategy more proficiently. In the light of this theory, although the CSCMS details various continuous improvement techniques, and although these techniques are related to quality issues, there is a gap with grounded theory. Although, as the CSCMS states that the QS9000 quality principles (discussed later) should be incorporated, the CSCMS does not emphasise that all the continuous improvement techniques should be linked to improving quality. Also the PDCA cycle should be included as part of the continuous improvement process. This is important, as the PDCA cycle is the sequence of activities, which are undertaken on a cyclical basis to improve activities, and thus should be driven down to be included in Plant-Specific maintenance plans.

Quality Management System: According to grounded theory, the key performance area or fundamental philosophy and principle underpinning the correct approach to maintenance management is the continuous satisfaction of customer needs. Customer satisfaction will be determined amongst others, by the organisation's ability to satisfy its customers' quality and service levels. Adopting a Total Quality approach to managing maintenance will improve teamwork, performance and safety, as well as reducing the risk of environmental damage. This includes conforming to ISO 9000 standards, reducing costs, and improved customer relationships. The CSCMS details that QS9000 principles should be incorporated with quality planning, quality maintenance, and quality products. However, at the time of writing, with Acerinox's acquisition of Columbus, the product strategy has shifted towards a more commodity based product mix. In addition changes in our operational management practices necessitated a review of the Quality Management System accreditation. During the Management review the Executive Management considered the above mentioned facts and decided that:

1. Columbus will de-list from TS 16949 and
2. The business will ensure compliance to ISO 9001:2000.

In the light of this, being a corporate strategy document, this new practice should be included for adoption by all plants and personnel.

Financial Control: World Class Maintenance theory suggests that financial control deals with the fiscal control procedures, and may include maintenance budget control, contractor cost monitoring, overall labour and material cost control, and decisions on asset repair/replacement. The CSCMS supports this practice by means of budgets, provisions and Capital Expenditure Applications. The CSCMS also states that assets should be replaced in accordance with the Asset Replacement Policy.

Planning and Scheduling: According to World Class Maintenance theory the lack of organised processes and standardised procedures can significantly restrict a maintenance operation from meeting its objectives of servicing the needs of the organisation. Increasing productivity or value-added work of maintenance personnel depends a great deal on properly planned activities. The CSCMS suggests that maintenance effectiveness can be optimised by shutdown management and effective integration with Planning and Production interface (PP&C) for optimised downtime, shutdowns, program changes, and no material delays. Generic roles have been developed for planners and they perform most of the planning for maintenance personnel on the CMMS.

Work Flow: World Class Maintenance theory states that the *work-order* is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems. There is a gap with the CSCMS in that although this is performed in each plant, there is no stipulation of this maintenance practice in the CSCMS. This should be included in the CSCMS as it gives a clear indication that the organisation should move towards becoming a World Class Maintenance Organisation.

4.5 Evaluation of the Hotmill Maintenance Plan (HMMP)

4.5.1 Scope and Purpose – Leadership and Policy Development

The HMMP stipulates that maintenance will support the Hotmill in the achievement of the production objectives and to ensure that the reliability and performance of the assets are increased. This HMMP should also depict the World Class Maintenance *Leadership and Policy Development* practice. However this is not readily apparent, as the following is not mentioned:

- Support for the CSCMS.
- There is no clear mission and vision supportive of the organisation's direction and goals.

4.5.2 Maintenance Organisation

The HMMP does extremely well in detailing the maintenance organisation as the combination of the self-sufficient shift team (SSST), the long-term maintenance technology support (MTS), and the control and instrumentation (C & I) dayshift team, and the team members of the Hotmill plant itself. Maintenance tasks have been allocated to various personnel in the maintenance organisations and are clearly mapped out in tables 3.1 to 3.8. The standardised structure as suggested by the CSCMS is not included in this HMMP, but is included in the plant's overall organogram.

4.5.3 Maintenance corporate policy

RCM: The CSCMS postulates that RCM philosophy should be applied to all plants. There is clear evidence of the HMMP utilising RCM methodologies, and various procedures have been drawn up based on RCM methodologies.

Spares Management/Inventory Control: The CSCMS echoes this by stipulating, "Effective spares management techniques are in place to reduce downtime risk, drive plant availability and reduce costs." The HMMP supports this by detailing how crucial spares must be identified, and that the relevant applications to stores must be filled in, and re-order levels must be clear. The HMMP also emphasises that all queries from the store must be handled.

The CSCMS adopts the Reliability Centred Spares (RCS) technique as a business standard for optimal spares holding, and the HMMP supports this. The HMMP goes further and details the design of line replaceable units (LRUs) for quick changing of spares.

Measurement and control of equipment and processes: The CSCMS stipulates seven points on continuous analysis, measurement and control. The HMMP administers statistical equipment control (SEC) and statistical process control (SPC) techniques. These state that equipment and processes that has been identified as critical is measured and the real-time information is stored on a database. All these data has to be preserved and the integrity of the information must be high to ensure good analysis.

Lifecycle Management: The whole maintenance philosophy of the HMMP is based on lifecycle management, which is based around the different stages, that equipment goes through while in use. The various activities concerned with the different stages are detailed in the HMMP and consist of:

- Specification stage;
- Procurement stage;
- QA check program;
- Store;
- Installation/Equipment exchange stage;
- Maintenance stage;
- Failure stage;
- Discard of equipment;
- Replacement; and
- Monitoring stage.

The HMMP does not state explicitly that the three approaches of maintenance – RTB, PM and CBM – should be used. However, this is implicated by the inclusion of all maintenance activities associated with the three types of maintenance that the HMMP stipulates namely, planned maintenance, running maintenance and breakdown management. The HMMP shows increased support of the CSCMS here, and also with the details concerning the planning of shutdowns, where work is categorised into:

- Preventative maintenance
- Predictive maintenance
- Improvements
- Re-engineering

Information: The HMMP includes details regarding the capturing of information. All maintenance information must be logged to specific systems, which will give the ability for analysis. In support of the CSCMS and World Class Maintenance practices, the HMMP emphasises as one of the golden rules of maintenance, that "providing the right information, at the right time, in the right place and format, to support decision-making."

The HMMP does not give any details about utilisation of a robust CMMS. However, most of the Planning and Work Control is performed on the CMMS. This CMMS is common to the all plants, and hence support in this area for the CSCMS and World Class Maintenance practices.

1st Line Maintenance: According to the HMMP, all shift managers must divide their plant into areas and allocate the equipment in these areas to specific groups or persons, who will maintain their equipment they are accountable for according to scheduled maintenance and inspection sheets. This will be done with the view of preventing the three evils as mentioned in the CSCMS – abuse, dirt, and lack of lubrication. The HMMP drives the key 9 principles of the *20-keys improvement program.* This entails:

- Dividing the plant in accountable areas;
- Initial cleaning;
- Implementation of easy access to difficult-to-reach areas;
- Asking "why" five times, which drives RCFA;
- Inspection sheets;
- Documentation; and
- Spares.

Developing People and Training: The HMMP supports the CSCMS policy of developing people by including in the plan, that "one of the most valuable assets in maintenance is our people." The HMMP indicates very clearly, which is in line with grounded theory, that:

- People must be developed to understand the science of maintenance as well as each maintenance process and how it coincides with other relative processes.

- People must be allowed to grow and develop in order to become more innovative.

The above is supported by two of the five golden rules of maintenance mentioned in the HMMP namely, Knowledge and People.

Continuous Improvement: This World Class maintenance practice is advocated in the expectations of the HMMP. It is indicated that the reliability and performance of assets will be increased through a program of continuous improvement. However, the HMMP states that the QS9000 quality principles (discussed later) should be incorporated, but it does not emphasise that all the continuous improvement techniques should be linked to improving quality or as per the Hotmill Quality Plan. This should be included in this HMMP to instil awareness of the Hotmill Quality Plan. Also the PDCA cycle should be included as part of the continuous improvement process. This is important, as the PDCA cycle is the sequence of activities, which are undertaken on a cyclical basis to improve activities, and thus should be included in the HMMP.

Quality Management System: In the light of the grounded theory as discussed in the CSCMS on this practice, the Hotmill has established its own plant-specific Quality Plan. This Quality Plan is not discussed in here, but it serves to mention that it is subservient to the quality policy and procedures of Columbus Stainless, and depicts the implementation of the quality policy and procedures in the Hotmill. However, as mentioned in the evaluation of this subject pertaining to the CSCMS, the accreditation to ISO9001:2000 Quality Management System should be included for adoption by all plant personnel.

Financial Control: The HMMP supports the CSCMS in stating the essentiality of understanding the impact and growth of money and costs, whether it is negative or positive, while managing maintenance. Also the "procure" stage in the lifecycle involves buying assets. The HMMP stipulates that Capex designs are done, IRR and ROI is calculated, and tenders are released for quotation by various vendors for best prices,

Planning and Scheduling: The CSCMS suggests that maintenance effectiveness can be optimised by shutdown management. The HMMP supports this practice by detailing all activities to be included with the planning and scheduling of a shutdown and all other maintenance activities, including deviations, contingencies, time chart complete with critical path and priorities, spares and resources.

Work Flow: As mentioned in the evaluation of the CSCMS on this practice, that according to World Class Maintenance theory on this practice, there is a gap with the CSCMS in that although this is performed in each plant, there is no stipulation of this maintenance practice in the CSCMS. This gap will thus exist between the HMMP and the CSCMS as well. This should also be included in the HMMP as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.

It must be stated that HMMP has been extended to include the various procedures detailing how each maintenance activity discussed above and more, should be carried out. This has been included as an extension to the HMMP as the Delivery and Availability upgrade plan. Each process is detailed, which references the procedure, flow diagram, and accountability sheet for each task involved.

4.6 Evaluation of the Steelplant Maintenance Plan (SPMP)

The Steelplant does not have a documented maintenance plan. However, the maintenance engineer, at the time of writing, of the Steelplant was asked to comment on the maintenance practices adopted at the Steelplant according to the CSCMS. This feedback will thus be referred to as the SPMP, and the evaluation will be conducted based on the feedback received.

4.6.1 Scope and Purpose – Leadership and Policy Development

This SPMP should also depict the World Class Maintenance *Leadership and Policy Development* practice. This is not readily apparent, as the following is not mentioned:

- Support for the CSCMS.
- There is no clear mission and vision supportive of the organisation's direction and goals.

4.6.2 Maintenance Organisation

The standardised structure as suggested by the CSCMS is not included in this SPMP, but is included in the plant's overall organogram.

4.6.3 Maintenance corporate policy

RCM: The SPMP states that the plant personnel are aware of RCM, however, it is not driven at the time of writing. Many trained facilitators are also available.

Spares Management/Inventory Control: The SPMP echoes the CSCMS in this, but has to optimise certain spares management practices. The allocation of stores item codes on all maintenance spares still has to be completed.

Measurement and control of equipment and processes: The SPMP considers this area of maintenance to be very important and supports the CSCMS strongly by supporting and driving the following areas as depicted in the CSMS:

- ➢ Continuous analysis, measurement and control for ongoing goal and policy alignment
- ➢ Establish cost effectiveness
- ➢ Measurement and reporting as per established KPA and KPI documents
- ➢ Relevant engineering indicators and results are made visible to the business
- ➢ Training structures in place on interpretation of the relevant indicators

➢ Corrective action is implemented from findings of analyses

Lifecycle Management: According to the SPMP, lifecycle management is also practiced, where the following approaches to maintenance takes place on various equipment:

- Scheduled maintenance (preventative)
- Condition based maintenance (predictive)
- Time based maintenance (overhaul, replace) – end-of-life, for example, every six months, some units are replaced, regardless.
- Breakdown maintenance (corrective)
- Design-out maintenance.

The SPMP has improved very much in this area with the assistance rendered by the stores personnel. The SPMP also supports the CSCMS intensely with regard to alignment with business processes in order to fulfil equipment lifecycle studies, availability of dedicated teams for lifecycle analysis, and availability of guidelines for reference purposes.

Information: The SPMP fully supports this practice by detailing the usage of maintenance information, which include amongst others, allowance for effective management decisions, training of all users of information and integration of new information systems to existing systems in line with the CSCMS. The SPMP also supports World Class Maintenance by having a robust CMMS system. The CMMS is common throughout the organisation, and as such is in line with stipulations of the CSCMS.

1st Line Maintenance: According to the SPMP, this is driven very strongly in the plant. The production personnel perform many maintenance tasks themselves, and also help the maintenance personnel during breakdowns and shutdowns. Very much is also done with regard to training production personnel to perform 1st line maintenance tasks, e.g. the elimination of the three maintenance evils – abuse/misuse, dirt and lack of lubrication. The Steelplant has gone a step further by arranging that Millwrights have their own assistants. These persons are also regarded as 1st line maintenance personnel, and are empowered to accept responsibility and being accountable.

Developing People and Training:
The CSCMS has formulated all the major maintenance related training courses that are available to all relevant personnel in line with a maintenance role skills matrix. The SPMP conforms to only 58% of these training courses. However, plant-specific technical staff are made available for training. All maintainers are not taking part in the knowledge exchange program at the required level as suggested by the CSCMS.

Also, as part of its continuous improvement techniques, the SPMP supports the CSCMS for a continuous drive for people upliftment, succession career planning, and systemising relevant knowledge.

Continuous Improvement: In the light of the theory on this maintenance practice, the SPMP drives this to a great extent according to details specified in the CSCMS. The SPMP should include in its maintenance plan, the PDCA cycle as part of the continuous improvement process. This is important, as the PDCA cycle is the sequence of activities, which are undertaken on a cyclical basis to improve activities, and thus should be driven down to all plant personnel.

Quality Management System: The SPMP gives a clear indication that QS9000 principles are not incorporated with quality planning, quality maintenance, and quality products. The main reason for this could be due to the de-listing of QS9000/TS16949 Quality Management System and accreditation to ISO9001: 2000 system. In the light of this, this compliance to the new Quality Management System should be included in the maintenance plan.

Financial Control: The SPMP supports this practice by means of budgets, provisions and Capital Expenditure Applications. The SPMP also indicates that with a new "Casper" information system, they will be able to compare month/month and year/year financial control. Also there are clear indications of adoption of the CSCMS policy with regard to assets being replaced in accordance with the Asset Replacement Policy.

Planning and Scheduling: The SPMP is intensely involved with shutdown planning. Their extensive utilisation of contractors to perform various maintenance activities necessitates this, and is committed to:

- Performing all planned work, as per pre-shutdown meetings;
- Optimise shutdowns to ensure required throughput and quality; and
- Performing opportunistic maintenance when possible – off-line task planning is in place.
- Effective generation of external labour contracts, which is controlled by the plant, and not via Central Engineering Services, as stipulated in the CSCMS, for repairs on various equipment,
- Limiting of external labour to shutdowns, and major breakdowns.

There is also a strong existence of ad-hoc shutdown audits (pre- and post-planning, execution, history, standards, etc.) Generic roles have been developed for planners and they perform most of the planning for maintenance personnel on the plant-wide common CMMS.

Work Flow: As mentioned in the evaluation of the CSCMS on this practice, that according to World Class Maintenance theory on this practice, there is a gap with the CSCMS in that although this is performed in each plant, there is no stipulation of this maintenance practice in the CSCMS. This gap will thus exist between the SPMP and the CSCMS as well. This should also be included in the SPMP as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.

4.7 Evaluation of the Maintenance Management by plant personnel at the Hotmill and Steelplant

Methodology

A Maintenance management maturity assessment was also concluded to target the maintenance personnel and the general management at the two plants namely the Hotmill and Steelplant. The intention of evaluating the maintenance maturity level is to get an indication of what level of maintenance management or maintenance excellence, according to grounded theory, each plant and the overall Hot End of the business is at currently. In order to do this a self-administered Maintenance Management Questionnaire (See Appendix one for Questionnaire) that was utilised previously by the internal Central Engineering Services department was adapted, and sent via e-mail to various plant personnel at the two plants. A few questionnaires were hand delivered to personnel that do not have e-mail. It was less costly, and easier to reach shift work personnel and others who might otherwise be inaccessible. Also, this was an easier means for data collection. Descriptive statistics is used to analyse the data received. A stratified random sampling technique was used where the researcher:

- Used a sampling frame of 354, based on a list of all plant personnel at the two plants. At the time of writing, the total number of plant personnel in the Steelplant equalled 151, and the total number of plant personnel in the Hotmill equalled 203.
- Divided the sampling frame into subgroups, such as Management, Artisan/Technician, Supervisory and Administration. These subgroups were selected in order to cover all plant personnel that make-up and contribute to maintenance, production, availability, costs, OEE, etc. of the plant. This was also done with a view to secure homogeneity within subgroups and heterogeneity between subgroups.
- Utilised a random sample from each subgroup from each plant, and a total sample of 90 respondents was chosen – 44 from the Steelplant and 46 from the Hotmill.

- Generated a bar graph indicating a maintenance maturity level for identified maintenance elements in the Steelplant, Hotmill and these combined areas - the Hot End of the business.
- Calculated measures of location, spread, and shape for each statement in the survey for the above-mentioned areas.

Figure 4.1 was adapted from grounded theory on the evolution of maintenance and World Class/Best Practice maintenance practices to rate the level of maintenance excellence that each plant and the overall Hot End of the business has attained, with the percentage ratings indicated. All these practices have been tested in the survey.

Level 5 – Excellence - World Class/Best Practice maintenance established. "We don't expect breakdowns and are surprised when they occur; maintenance contributes to bottom line" >80%	• An integrated Corporate maintenance strategy/asset strategy is in place. • Asset users are accountable for current asset performance. • Operators have appropriate maintenance skills; perform care and monitoring tasks – autonomous work teams, with maintenance staff concentrating on improving asset performance. • Well-qualified workforce (multi-skilled) in lean structure. • Equipment failures – not justified as run-to-failure – are rare. • There is a database and key performance indicators on equipment effectiveness; benchmarking and continuous improvement. Audit procedures are implemented regularly with reviews of process cost, time and quality. • A fully integrated information system with common database is an integral part of the maintenance management process. This incorporates an integrated maintenance and production planning system for planning and scheduling. • All maintenance tactics employed, such as PM, based on full value-risk program. • Asset management is discussed as an agenda item at board meetings, and spares holding are based on risk and cost analysis. • Advanced financial models used in decision-making.
Level 4 – Wisdom - continuous improvement, use of World Class/Best Practice techniques, reliable and accurate information. "Everyone is committed to quality maintenance as a routine part of our operational philosophy" 70 – 79%	• Senior management commitment is evident. • A comprehensive maintenance strategy guideline is available. • Predictive maintenance is preferred. • RCM is performed. • Continuous improvement is formal, cross-functional and participative. • Management performance and key performance indicators are defined, measured and regularly reported. • Maintenance budget and cost per equipment is based on history analysis, and is linked to the workload. Cost of non-conformance is monitored. • Maintenance is recognised as an important investment. • Information management is fully functional and linked to financial and materials systems. • Estimated times are used in planning and scheduling. • Some RCM, CBM, PM, FMEA techniques are used. • Spares holding is regularly reviewed and linked to schedules.
Level 3 – Acceptance/Understanding that reactive maintenance is wrong. "We can begin to identify and solve problems" 60 – 69%	• Routine maintenance is well established. • There is a disciplined computerised work order system. • A short-term plan is in place, with an official maintenance objective published. • A fully trained staff and well-structured maintenance department. • Some commitment to continuous improvement in maintenance. • Machine efficiency is measured and downtime is defined by cause. More indicators, trends and other management reports are generated, with well-maintained history records. • The information system id fully functional, but not linked to other systems. • There are attempts to link the maintenance budget to a planned workload. Strict expenditure control exists. • Spares are computerised with accurate information. • Senior management occasionally discusses maintenance.

Level 2 – Awareness of maintenance as a potential improvement area. 50 – 59%	• PM plan in place, but not followed. Mainly reactive work pattern. Time based inspections are implemented, but collected data is not analysed. • Staff not suitably qualified. • Some planning of shutdowns and key overhauls. • Overtime worked to a regular pattern. • No maintenance budgeting and control in place. • Lack of support for proposals to improve maintenance. Continuous improvement consists of a one-time review of maintenance process. • No top-down or user involvement. • Operators given some maintenance responsibility. • There are some maintenance reports. • There is an unofficial objective to "support production". • Information system entails partial use of recognised maintenance software. • Stores are organised, but spares information is not accurate. • There are attempts at introducing a work order system. Some work is prioritised and inspection scheduling takes place.
Level 1 – Little awareness of maintenance/uncertainty. "We don't know why the equipment breaks down" <49%	• Fire fighting ("if it breaks, fix it"). Mostly reactive to breakdowns. • There is total reliance on the individual attitudes of the maintenance crew. Roles and responsibilities are not clarified. • There is no TPM awareness. • No clear top-down commitment. • There is an unofficial objective to "respond quickly to request". • Maintenance costs are not available, and no performance reports generated. • Information systems are virtually non-existent with many manual systems. • PM consists only of shutdown inspections, with no failure records. • There is little or no planning and scheduling of maintenance work. • Weekend and other overtime accepted as the norm • Spares availability is low.

Figure 4.1: Maintenance Management Maturity levels

Results of Maintenance Management Survey

Figure 4.2 tables indicate the results from the survey based on an overall response rate of 56.38% (43.75% from the Steelplant, and 69.57% from the Hotmill) within one week. Certain practices from the survey will be discussed, some in greater detail than others.

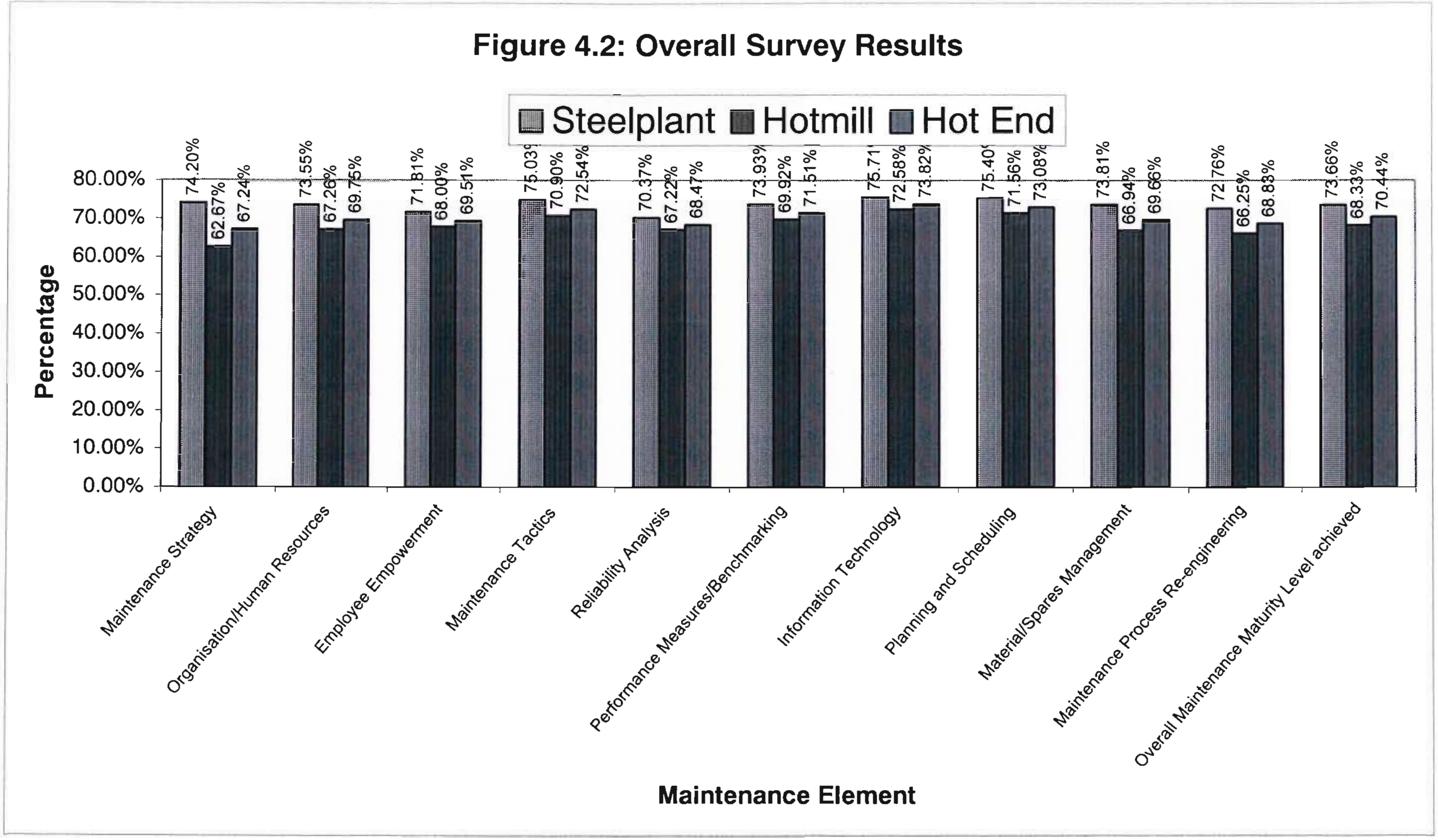


Figure 4.2: Overall Survey Results
Steelplant
Hotmill
Hot End
Percentage
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
74.20%
62.67%
67.24%
73.55%
67.26%
69.75%
71.81%
68.00%
69.51%
70.90%
72.54%
70.37%
67.22%
68.47%
69.92%
71.51%
72.58%
73.82%
71.56%
73.08%
73.81%
66.94%
72.76%
66.25%
68.83%
73.66%
68.33%
70.44%
Maintenance Strategy
Organisation/Human Resources
Employee Empowerment
Maintenance Tactics
Reliability Analysis
Performance Measures/Benchmarking
Information Technology
Planning and Scheduling
Material/Spares Management
Maintenance Process Re-engineering
Overall Maintenance Maturity Level achieved
Maintenance Element

Tables 4.1 and 4.2 shows the summaries of the descriptive statistics on the Strategy Maintenance Element as per survey. The measure of location, measures of spread, and measures of shape are shown.

	Measures of Location SP			Measures of Location HM			Measures of Location HE			Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode	Variance	Std Deviation	Range	Variance	Std Deviation	Range	Variance	Std Deviation	Range
Statement1	3.48	4.00	4.00	2.81	2.50	2.00	3.08	3.00	2.00	1.06	1.03	3	1.51	1.23	4	1.42	1.19	4
Statement2	3.76	4.00	4.00	3.56	4.00	4.00	3.64	4.00	4.00	0.39	0.62	3	0.83	0.91	4	0.66	0.81	4
Statement3	3.67	4.00	4.00	3.31	3.00	4.00	3.45	4.00	4.00	1.03	1.02	3	0.87	0.93	4	0.94	0.97	4
Statement4	3.62	4.00	4.00	3.13	3.00	4.00	3.32	3.00	4.00	0.75	0.86	3	0.82	0.91	3	0.84	0.92	4
Statement5	3.81	4.00	4.00	3.16	3.00	4.00	3.42	4.00	4.00	0.76	0.87	3	0.78	0.88	3	0.86	0.93	3
Statement6	3.86	4.00	4.00	3.28	3.50	4.00	3.51	4.00	4.00	0.63	0.79	3	0.79	0.89	3	0.79	0.89	3
Statement7	3.67	4.00	4.00	2.91	3.00	4.00	3.21	3.00	4.00	1.23	1.11	4	0.93	0.96	3	1.17	1.08	4
Statement8	3.62	4.00	4.00	2.69	2.50	2.00	3.06	3.00	4.00	0.75	0.86	4	0.93	0.97	4	1.05	1.03	4
Statement9	3.67	4.00	4.00	2.84	3.00	2.00	3.17	3.00	4.00	0.73	0.86	4	0.91	0.95	3	0.99	0.99	4
Statement10	3.81	4.00	4.00	3.28	3.50	4.00	3.49	4.00	4.00	0.56	0.75	3	0.79	0.89	3	0.75	0.87	4
Statement11	3.86	4.00	4.00	3.50	4.00	4.00	3.64	4.00	4.00	0.73	0.85	3	0.97	0.98	4	0.89	0.94	4

Table 4.1: Measures of Location and Spread on Strategy Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement1	-0.23	-1.06	0.27	-1.04	-0.01	-1.12
Statement2	-1.16	2.42	-0.87	0.91	-1.04	1.51
Statement3	-0.50	-0.71	-0.43	-0.05	-0.38	-0.44
Statement4	-0.15	-0.38	-0.54	-0.92	-0.38	-0.46
Statement5	-0.59	0.12	-0.02	-1.15	-0.19	-0.90
Statement6	-1.06	1.62	-0.31	-1.16	-0.54	-0.64
Statement7	-0.95	0.35	-0.27	-1.08	-0.34	-0.82
Statement8	-1.69	3.55	0.46	-0.34	-0.23	-0.91
Statement9	-1.90	4.31	-0.14	-1.11	-0.60	-0.71
Statement10	-0.45	0.54	-1.20	0.87	-0.98	1.18
Statement11	-0.77	0.59	-0.76	0.07	-0.79	0.25

Table 4.2: Measure of Shape on Strategy Maintenance element as per survey

From figure 4.2 and tables 4.1 and 4.2 with regard to the Strategy maintenance element, the following can be noticed:

- A conclusion can be made that the plant personnel at the Steelplant are unsure of the CSCMS. This is supported by the mean for statement 1, which is equal to 3.48. However, the mode of 4 states that from the sample taken, the majority of the plant personnel agree that they are aware of the CSCMS, and midpoint of the distribution is also a value of 4, meaning that 50% of the respondents strongly disagree, disagree or are not sure. By comparing the values of the mean and the median, it will be noticed that the values received for this statement are spread apart from each other. This can be confirmed with a standard deviation of 1.03, that ±68% of the plant personnel are unaware of the CSCMS. With the ratio of the range to the standard deviation equal to 2.91, reveals the homogenous nature of the distribution.
- From the evaluation of the SPMP, it was found that no maintenance plan for the Steelplant exists. The results from the survey on having a defined long-term maintenance plan or strategy that is linked to the CSCMS (statement 2 mean value = 3.76) indicates that the plant personnel do not know that a maintenance plan does exist. However, with a mode of 4, this means that the majority of the respondents agree that a maintenance plan exists, and supports the CSCMS, but the median of 4 reveals that 50% of the values lay from 1 to 3. This means that 50% of the respondents strongly disagree, disagree or are not sure that a maintenance plan for the plant exists. The ratio of the range to the standard deviation of 4.8 indicates the homogeneity of the distribution.
- Similar results to the above are obtained for all statements regarding the Strategy element of maintenance management. From figure 4.2, the maintenance maturity assessment with regard to Maintenance Strategy, which is also in line with the World Class/Best Practices maintenance practice of *Leadership and Policy Development*, scores 74.20%. This value indicates that strategy is apparent at the

Steelplant, but as can be seen from the measures of location, this is not very focussed.

- The plant personnel at the Hotmill disagree that they are aware of the CSCMS. From the sample taken a mean of 2.81, and a standard deviation of 1.23 confirms that ±68% of the Hotmill personnel disagree with the awareness of the CSCMS. This is also supported with a value of 2 for the mode. Much has to be done in this area to increase awareness of the CSCMS. The ratio of the range to the standard deviation of 3.25 indicates the homogenous nature of the distribution.
- Although the Hotmill has a maintenance plan, many plant personnel are not sure whether they have a long-term maintenance plan or strategy (statement 2). A mean value of 3.56 and a standard deviation of 0.91 indicate that there is very little variability with this statement. However, the mean value could be deceiving if one has to realise that majority of the respondents answered that they agree (Mode = 4, and Median =4) there is a maintenance plan. The ratio of the range to the standard deviation of 4.39 reveals the homogeneity of the distribution.
- From figure 4.2 the Hotmill has a maintenance maturity level with regard to the maintenance strategy element of 62.67%. This is an "average" maturity level when benchmarking against 100% (full score for all statements in this element). The plant personnel at the Hotmill need to improvement cooperation between the production and the maintenance personnel (statement 8). This is evident from achieving a mean of 2.69, a median of 2.5, and a mode of 2, with a standard deviation of 0.97. This means that ±68% of the plant personnel disagree that cooperation exists between production and maintenance personnel. Every effort needs to be exerted with this, as it is important with *Planning and Scheduling* to liase with each other, especially on shutdowns and no program delays.
- The overall maintenance maturity level for maintenance strategy at the Hot End (HE) of the business reveals that it is "average" (a value of 67.24% vs. benchmark full score for all statements in this strategy element) indicates that strategy is apparent, but not really focussed. If

the CSCMS is to support the manufacturing strategies as lay down by Acerinox, then a more focussed effort has to be exerted with maintenance strategy development at the Hot End of the business.

From figure 4.2 and tables 4.3 and 4.4 with regard to the Organisation/Human Resources maintenance element, the following can be noticed:

- The Steelplant has a maintenance maturity level of 73.55% (figure 4.2) for the Organisation/human resources maintenance element of the survey. Organisational efficiency is apparent by the favourable scores received for:
  - Employees understanding of what is expected of them with fully defined functions covering plant needs (statement 15). This is almost a symmetrical distribution, which is supported with values for the mean, median and mode of 4.10, 4 and 4 respectively, all of which are in the same location. This is further supported by the Skewness of –0.13, which indicates that the majority of the respondents agree with this maintenance statement.
  - A similar analysis as above of results for adequate, highly skilled and experienced staffing level (statement 16) is revealed. The symmetrical distribution supporting this statement is achieved from the mean, median and mode lying in the same location with a value of 4, indicating without doubt the agreement with this statement by majority of the respondents.
  - According to the evaluation of the SPMP, the Steelplant utilises a lot of contractors for maintenance activities. This is supported by statement 20 of the survey, which indicates a symmetrical distribution achieved from the mean, median and mode lying in the same location with values of 4.05, 4 and 4 respectively.

	Measures of Location SP			Measures of Location HM			Measures of Location HE			Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode	Variance	Std Deviation	Range	Variance	Std Deviation	Range	Variance	Std Deviation	Range
Statement12	3.90	4.00	4.00	3.44	4.00	4.00	3.62	4.00	4.00	0.59	0.77	3	0.58	0.76	2	0.62	0.79	3
Statement13	3.76	4.00	4.00	3.16	3.00	4.00	3.40	4.00	4.00	0.49	0.70	3	0.85	0.92	4	0.78	0.88	4
Statement14	3.67	4.00	4.00	3.25	4.00	4.00	3.42	4.00	4.00	1.03	1.02	4	0.97	0.98	4	1.02	1.01	4
Statement15	4.10	4.00	4.00	3.72	4.00	4.00	3.87	4.00	4.00	0.49	0.70	2	0.34	0.58	3	0.42	0.65	3
Statement16	4.00	4.00	4.00	3.44	4.00	4.00	3.66	4.00	4.00	0.50	0.71	3	1.03	1.01	4	0.88	0.94	4
Statement17	3.71	4.00	4.00	3.56	4.00	4.00	3.62	4.00	4.00	0.71	0.85	3	0.71	0.84	3	0.70	0.84	3
Statement18	3.00	3.00	3.00	2.78	3.00	2.00	2.87	3.00	2.00	0.90	0.95	4	1.34	1.16	4	1.16	1.07	4
Statement19	3.43	4.00	4.00	3.28	3.00	3.00	3.34	3.00	4.00	0.46	0.68	2	0.72	0.85	3	0.61	0.78	3
Statement20	4.05	4.00	4.00	4.00	4.00	4.00	4.02	4.00	4.00	0.65	0.80	3	0.26	0.51	2	0.40	0.64	3
Statement21	3.57	4.00	4.00	3.34	4.00	4.00	3.43	4.00	4.00	0.66	0.81	3	1.20	1.10	4	0.98	0.99	4
Statement22	3.86	4.00	4.00	3.16	3.00	3.00	3.43	4.00	4.00	0.53	0.73	2	0.78	0.88	3	0.79	0.89	4
Statement23	3.48	4.00	4.00	3.50	4.00	4.00	3.49	4.00	4.00	1.06	1.03	3	0.58	0.76	3	0.75	0.87	3
Statement24	3.29	3.00	3.00	3.09	3.00	4.00	3.17	3.00	4.00	0.81	0.90	4	1.12	1.06	4	0.99	0.99	4

Table 4.3: Measures of Location and Spread on Organisation/Human resources Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement12	-1.29	2.56	-0.95	-0.54	-0.91	0.22
Statement13	-0.60	1.00	-0.33	-0.48	-0.54	-0.12
Statement14	-1.13	1.31	-0.54	-0.82	-0.69	-0.32
Statement15	-0.13	-0.76	-0.96	1.39	-0.30	0.47
Statement16	-0.94	2.44	-0.41	-0.27	-0.70	0.25
Statement17	-0.48	0.05	-0.38	-0.31	-0.40	-0.29
Statement18	0.00	-0.01	0.19	-0.90	0.08	-0.70
Statement19	-0.79	-0.35	0.07	-0.58	-0.19	-0.57
Statement20	-0.73	0.70	0.00	1.39	-0.48	1.25
Statement21	-0.88	0.14	-0.28	-0.90	-0.49	-0.61
Statement22	0.23	-0.94	-0.92	0.34	-0.65	0.78
Statement23	-0.23	-1.06	-0.70	-0.18	-0.43	-0.61
Statement24	-0.64	0.93	-0.20	-0.70	-0.35	-0.36

Table 4.4: Measures Shape on Organisation/Human Resources Maintenance Element as per survey

- The Hotmill has a maintenance maturity level of 67.26% (figure 4.2) for the Organisation/human resources maintenance element of the survey. Organisational efficiency is not very apparent with favourable scores obtained only for:
  - The usage of contractors during shutdowns and/or specific projects or specialised work (statement 20). The symmetrical distribution supporting this statement is achieved from the mean, median and mode lying in the same location with a value of 4, indicating without doubt the agreement with this statement by majority of the respondents.

  The Hotmill structure of first line supervisors needs to be investigated for increased organisational efficiency. A mean of 2.78, and a mode of 2, indicates that the respondents disagree that first line supervisors are responsible for at least 12 to 15 maintenance workers. It is however, not apparent whether the ratio of first line supervisors to maintenance workers is too high or too low.
- The overall maintenance maturity level for Organisation/Human resources maintenance element of the survey at the Hot End of the business reveals that it is slightly above "average" (a value of 69.75% vs. benchmark full score for all statements in this strategy element) indicating that organisational efficiency is apparent, but not really focussed. A more focussed effort has to be exerted with organisation/human resources maintenance element development at the Hot End of the business in order to reach World Class Standards.

From figure 4.2 and tables 4.5 and 4.6 with regard to the Employee Empowerment maintenance element, the following results can be highlighted:

- Both the Steelplant and the Hotmill bring the mean of the Employee Empowerment maintenance element to 4.19. This is supported by the median and the mode of 4. Majority of respondents agree operations can rely strongly on getting quick and efficient maintenance support after hours (statement 31).

	Measures of Location SP			Measures of Location HM			Measures of Location HE			Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode	Variance	Std Deviation	Range	Variance	Std Deviation	Range	Variance	Std Deviation	Range
Statement25	3.67	4.00	4.00	2.97	3.00	4.00	3.25	4.00	4.00	1.03	1.02	4	1.19	1.09	4	1.23	1.11	4
Statement26	3.71	4.00	4.00	3.31	3.50	4.00	3.47	4.00	4.00	0.41	0.64	3	0.61	0.78	2	0.56	0.75	3
Statement27	3.57	4.00	4.00	3.56	4.00	4.00	3.57	4.00	4.00	1.26	1.12	3	0.58	0.76	3	0.83	0.91	3
Statement28	3.24	4.00	4.00	3.41	4.00	4.00	3.34	4.00	4.00	1.39	1.18	4	0.83	0.91	3	1.04	1.02	4
Statement29	3.52	4.00	4.00	3.09	3.00	3.00	3.26	3.00	3.00	0.46	0.68	3	0.67	0.82	3	0.62	0.79	4
Statement30	3.81	4.00	4.00	3.66	4.00	4.00	3.72	4.00	4.00	0.86	0.93	3	0.56	0.75	3	0.67	0.82	3
Statement31	4.19	4.00	4.00	4.19	4.00	4.00	4.19	4.00	4.00	0.26	0.51	2	0.48	0.69	3	0.39	0.62	3
Statement32	3.62	4.00	4.00	3.53	4.00	4.00	3.57	4.00	4.00	1.45	1.20	4	1.03	1.02	4	1.17	1.08	4
Statement33	3.52	4.00	4.00	3.50	4.00	4.00	3.51	4.00	4.00	0.96	0.98	3	0.97	0.98	4	0.95	0.97	4
Statement34	3.05	3.00	3.00	2.78	3.00	3.00	2.89	3.00	3.00	0.85	0.92	3	0.63	0.79	3	0.72	0.85	3

Table 4.5: Measures of Location and Spread on Employee Empowerment Maintenance Element as per survey

:

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement25	-1.13	1.31	-0.41	-0.70	-0.60	-0.43
Statement26	-0.91	1.51	-0.63	-1.05	-0.75	-0.35
Statement27	-0.20	-1.29	-0.46	-0.01	-0.28	-0.66
Statement28	-0.71	-0.87	-0.39	-0.90	-0.62	-0.63
Statement29	-0.09	0.08	-0.56	-0.23	-0.51	0.15
Statement30	-0.41	-0.45	-0.83	0.58	-0.52	0.00
Statement31	0.36	0.60	-0.89	2.00	-0.64	1.94
Statement32	-0.69	-0.50	-0.88	-0.03	-0.74	-0.33
Statement33	-0.60	-0.79	-0.76	0.07	-0.68	-0.33
Statement34	-0.95	0.56	0.01	-0.59	-0.37	-0.41

Table 4.6: Measures of Shape on Employee Empowerment Maintenance Element as per survey

- The majority of the respondents from the plants are not sure if the organisation is a "Command and Control" organisation (statement 34). The mean for the Hot End is 2.89, the median is 3, and the mode is 3. With a standard deviation of 0.85, means that very little variablility is found here. Also the ratio of the range to the standard deviation of 3.53, reveals the homogeneity of the distribution. It is important that empolyees feel empowered to take decisions on their own. This improves commitment and ownership of equipment, and allow, for example equipment operators to perform minor maintenance activities like cleaning, lubricating and minor adjustments – autonomous mintenance is practiced.
- From figure 4.2, the maintenance maturity level achieved by the Hot End for Employee Empowerment maintenance level is 69.51%, which is just above "average", when compared to a benchmark of 100% (full score for all statements in this category). Columbus Stainless has to drive TPM and RCM methodologies, and both these methodologies require the support and input of all plant personnel in order for it to be successful. This can be achieved by empowering employees, and affording them opportunites to "own" and make decisions with regard to their equipment.

The Maintenance Tactics maintenance element from the survey indicates that the Steelplant and the Hotmill are using text book approaches to maintenance in the respective plants, ie. PM and CBM. Figure 4.2 indicates that the Steelplant has achieved 75.03% maturity level, and the Hotmill 70.90% maturity level with the Maintenance Tactics maintenance element of the survey. This is above average when compared to the 100% benchmark that can be obtained (full score for all statement in this category) in order to reach World Class Standards. Although tables 4.7 and 4.8 indicate that the means for these statements are on average 3.75, the modes of 4 indicate that majority of the respondents agree that the maintenance tactics implememted in the respective plants are utilised accordingly.

	Measures of Location SP			Measures of Location HM			Measures of Location HE				Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode		Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement35	3.95	4.00	4.00	3.84	4.00	4.00	3.89	4.00	4.00		0.25	0.50	2	0.78	0.88	3	0.56	0.75	3
Statement36	3.67	4.00	4.00	3.53	4.00	4.00	3.58	4.00	4.00		0.53	0.73	3	0.71	0.84	3	0.63	0.80	3
Statement37	3.71	4.00	4.00	3.31	3.00	3.00	3.47	4.00	4.00		0.71	0.85	3	0.61	0.78	3	0.68	0.82	3
Statement38	3.71	4.00	4.00	3.66	4.00	4.00	3.68	4.00	4.00		0.71	0.85	3	0.43	0.65	3	0.53	0.73	3
Statement39	3.48	4.00	4.00	3.56	4.00	4.00	3.53	4.00	4.00		0.46	0.68	2	0.51	0.72	3	0.48	0.70	3
Statement40	4.00	4.00	4.00	3.97	4.00	4.00	3.98	4.00	4.00		0.50	0.71	3	0.35	0.59	2	0.40	0.64	3
Statement41	3.81	4.00	4.00	3.50	4.00	4.00	3.62	4.00	4.00		0.76	0.87	3	0.90	0.95	4	0.85	0.92	4
Statement42	3.76	4.00	4.00	3.53	4.00	4.00	3.62	4.00	4.00		0.49	0.70	3	0.58	0.76	3	0.55	0.74	3
Statement43	3.67	4.00	4.00	3.00	3.00	3.00	3.26	3.00	4.00		0.93	0.97	4	0.77	0.88	4	0.93	0.96	4

Table 4.7: Measures of Location and Spread on Maintenance Tactics Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement35	-0.13	1.86	-0.87	0.44	-0.94	1.35
Statement36	-1.07	1.13	-0.28	-0.39	-0.53	-0.13
Statement37	-1.03	0.73	-0.19	-0.57	-0.44	-0.51
Statement38	-1.03	0.73	-1.00	1.01	-0.97	0.77
Statement39	-0.96	-0.10	-0.80	0.23	-0.82	0.01
Statement40	-0.94	2.44	0.00	0.11	-0.45	1.13
Statement41	-0.59	0.12	-0.96	0.33	-0.83	0.35
Statement42	-1.56	2.77	-0.81	-0.03	-1.03	0.50
Statement43	-1.08	1.83	0.00	-0.18	-0.30	-0.24

Table 4.8: Measures of Shape on Maintenance Tactics Maintenance Element as per survey

There is also strong support for World Class/Best Practice maintenance practices by agreement obtained by majority of the respondents, that CBM techniques such as vibration analysis, oil sampling, etc (Statement 40) are used strongly.

Figure 4.2 indicates that the maturity level for Reliability Analysis maintenance element achieved from the survey for the Steelplant and Hotmill is 70.37% and 67.22% respectively. Also from tables 4.9 and 4.10, it will noticed that the respondents in the Steelplant are unsure that a formal analysis such as RCM or TPM (statement 52) is used to determine the optimum maintenance routines on equipment. This is supported with a mean of 3.33. However, the median and mode of 4 indicate that 50% of the respondents agree, some strongly, that a formal analysis is used. From the evaluation of the SPMP, it was revealed that RCM is not driven at the Steelplant. In the light of this, it can be assumed that TPM or some other analysis methodology other than RCM is apparent, but not focussed on, or the principles of RCM are used to a greater extent. The standard deviation is 1.11 here also reflects on the amount of variability of individuals within the sample.

The respondents from the Hotmill indicate that they disagree that a formal analysis methodology such RCM or TPM is used. The mean for the results from this statement is 2.97, with a median and mode of 3. In the light of the Hotmill having a detailed maintenance plan, with extensive procedures on how to carry out various RCM maintenance activities, the majority of the respondents fall in the category of disagreeing, with almost one standard deviation of 0.93. The ratio of the range to the standard deviation of 3.23 supports the homogeneous nature of this distribution. An assumption can be made that although the methodology is well documented, people are either not aware of the maintenance plan or the methodology as detailed in the maintenance plan is not been implemented strongly. Also, it can be assumed that the plant personnel are aware of the performance expected utilising the RCM principles, but are in fact admitting to not meeting these performances and objectives. If this is the case, then the results are warranted.

	Measures of Location SP			Measures of Location HM			Measures of Location HE			Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode	Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement44	3.76	4.00	4.00	3.38	4.00	4.00	3.53	4.00	4.00	0.29	0.54	2	0.63	0.79	3	0.52	0.72	4
Statement45	3.67	4.00	4.00	3.50	4.00	4.00	3.57	4.00	4.00	0.83	0.91	3	0.58	0.76	3	0.67	0.82	3
Statement46	3.52	4.00	4.00	3.66	4.00	4.00	3.60	4.00	4.00	0.96	0.98	4	0.56	0.75	3	0.71	0.84	4
Statement47	3.71	4.00	4.00	3.44	4.00	4.00	3.55	4.00	4.00	0.81	0.90	3	0.71	0.84	3	0.75	0.87	3
Statement48	3.24	3.00	4.00	3.16	3.00	4.00	3.19	3.00	4.00	1.19	1.09	4	0.72	0.85	3	0.89	0.94	4
Statement49	3.14	3.00	4.00	3.09	3.00	3.00	3.11	3.00	3.00	1.03	1.01	4	0.67	0.82	3	0.79	0.89	4
Statement50	3.86	4.00	4.00	3.59	4.00	4.00	3.70	4.00	4.00	0.63	0.79	3	0.96	0.98	4	0.83	0.91	4
Statement51	3.43	3.00	4.00	3.47	4.00	4.00	3.45	4.00	4.00	0.56	0.75	3	0.84	0.92	4	0.71	0.85	4
Statement52	3.33	4.00	4.00	2.97	3.00	3.00	3.11	3.00	4.00	1.23	1.11	4	0.87	0.93	3	1.03	1.01	4

Table 4.9: Measures of Location and Spread on Reliability Analysis Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement44	-0.20	0.03	-1.22	1.17	-1.21	1.93
Statement45	-0.55	-0.25	-0.70	-0.18	-0.55	-0.26
Statement46	-0.95	1.00	-0.83	0.58	-0.95	1.01
Statement47	-0.72	0.05	-0.66	-0.67	-0.61	-0.45
Statement48	-0.27	-0.71	-0.65	-0.35	-0.39	-0.48
Statement49	-0.31	-0.58	-0.56	-0.23	-0.40	-0.41
Statement50	-0.39	0.15	-1.27	1.65	-1.09	1.64
Statement51	-0.13	-0.09	-1.38	1.76	-1.04	1.26
Statement52	-0.74	0.17	-0.44	-0.75	-0.47	-0.45

Table 4.10 Measures of Shape on Reliability Analysis Maintenance Element as per survey

Notwithstanding the reasons for the results obtained a lot of effort is required in both plants to improve reliability analysis, in order to reach World Class/Best Practices standards, and hence support the availability of equipment to support production requirements.

According to figure 4.2 and tables 4.11 and 4.12, the Steelplant has again scored higher in terms of Performance Measures/Benchmarking maintenance practices and the following can be highlighted:

- The maintenance maturity level with regard to this practice is 73.93% for the Steelplant, and 69.92% for the Hotmill. The indication here is that machine efficiency is measured and key performance indicators are defined and measured more strongly in the Steelplant. This is supported by obtaining a mean of 4.10, with a mode and median of 4 for statement 54. This indicates with a standard deviation of 0.70, that the majority of the respondents agree that downtime records including causes are kept on key equipment and systems.
- However the variance and standard deviation for other practices under the Performance Measure/Benchmarking maintenance element indicate a greater amount of spread in the distribution from the Steelplant as compared to the Hotmill, thus a level of uncertainty on various issues could exist.
- The overall Hot End mean values (ranging from 3.26 to 3.87) for the issues surveyed under this category, indicate that a great deal of unawareness is evident in both plants, and key performance indicators should be communicated and measured in order to improve overall performance and measure trends.

	Measures of Location SP			Measures of Location HM			Measures of Location HE				Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode		Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement53	3.76	4.00	4.00	3.56	4.00	4.00	3.64	4.00	4.00		0.59	0.77	3	0.64	0.80	3	0.62	0.79	4
Statement54	4.10	4.00	4.00	3.72	4.00	4.00	3.87	4.00	4.00		0.49	0.70	3	0.47	0.68	3	0.50	0.71	3
Statement55	3.90	4.00	4.00	3.63	4.00	4.00	3.74	4.00	4.00		0.89	0.94	3	0.31	0.55	2	0.54	0.74	3
Statement56	3.86	4.00	4.00	3.50	4.00	4.00	3.64	4.00	4.00		1.13	1.06	3	0.58	0.76	3	0.81	0.90	3
Statement57	3.76	4.00	4.00	3.56	4.00	4.00	3.64	4.00	4.00		1.09	1.04	4	0.77	0.88	3	0.89	0.94	4
Statement58	3.52	4.00	4.00	3.41	4.00	4.00	3.45	4.00	4.00		1.36	1.17	4	1.15	1.07	4	1.21	1.10	4
Statement59	3.24	3.00	4.00	3.28	3.00	4.00	3.26	3.00	4.00		1.29	1.14	4	0.66	0.81	3	0.89	0.94	4
Statement60	3.43	4.00	4.00	3.31	3.00	3.00	3.36	4.00	4.00		1.56	1.25	4	0.61	0.78	3	0.97	0.98	4

Table 4.11: Measures of Location and Spread on Performance Measures/Benchmarking Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement53	-0.28	0.12	-1.83	2.62	-1.23	1.91
Statement54	-1.10	3.25	-0.87	1.15	-0.82	1.33
Statement55	-0.58	-0.30	0.08	-0.85	-0.13	-0.18
Statement56	-0.80	-0.41	-0.70	-0.18	-0.52	-0.42
Statement57	-1.22	1.47	-0.51	-0.41	-0.79	0.25
Statement58	-0.58	-0.53	-0.91	-0.19	-0.73	-0.39
Statement59	-0.52	-0.30	-0.19	-0.76	-0.42	-0.21
Statement60	-0.93	0.06	-0.19	-0.57	-0.66	0.21

Table 4.12 Measures of Shape on Performance Measures/Benchmarking Maintenance Element as per survey

Figure 4.2 and tables 4.13 and 4.14 show that the maintenance maturity level with regard to maintenance practices associated with Information technology at the Hot End of the business, is at a level of 73.82%, with the Steelplant achieving 75.71% and the Hotmill 72.58%. The following aspects warrant special mention:

- The mean value of 4.02 indicates that plant personnel at the Hot End of the business agree that scheduling for major shutdowns is done using a project management system that determines critical path and required level of resources. The standard deviation of 0.69 is also a good indication of the low level of variability of individuals in this distribution, and is supported by a ratio of 4.34 of the range to the standard deviation, indicating the homogeneity of the distribution.
- However, with the mean values ranging from 3.36 to 3.91 for the other practices relating to information technology, it is apparent that there also exists a great deal of unawareness. Awareness with regard to the benefits of utilising robust information technology as a maintenance tool needs to be instilled in plant personnel at the Hot End of the business. Grounded theory does state that successful maintenance practices depend a great deal on robust information systems.

The Hot End of Columbus Stainless has scored 73.08% (figure 4.2) with a maintenance maturity level on Planning and Scheduling maintenance element. According to tables 4.15 and 4.16, this result has been achieved because of the following:

- A mean value of 4.05 with a standard deviation of 0.80 is evidence of the fact that the Steelplant personnel agree that work orders are used extensively for maintenance work (statement 69).
- A mean value of 4.10 with a standard deviation of 0.83 is indicative that Steelplant personnel agree that all non-emergency work requests are screened, estimated and planned by a dedicated planner (statement 72).

	Measures of Location SP			Measures of Location HM			Measures of Location HE				Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode		Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement61	3.67	4.00	4.00	3.75	4.00	4.00	3.72	4.00	4.00		1.13	1.06	4	0.52	0.72	3	0.75	0.86	4
Statement62	3.57	4.00	4.00	3.56	4.00	4.00	3.57	4.00	4.00		0.76	0.87	3	0.51	0.72	3	0.60	0.77	3
Statement63	3.76	4.00	4.00	3.72	4.00	4.00	3.74	4.00	4.00		0.69	0.83	3	0.47	0.68	3	0.54	0.74	3
Statement64	3.67	4.00	4.00	3.16	3.00	3.00	3.36	3.00	4.00		0.73	0.86	3	0.85	0.92	4	0.85	0.92	4
Statement65	3.76	4.00	4.00	3.44	4.00	4.00	3.57	4.00	4.00		0.49	0.70	2	0.51	0.72	2	0.52	0.72	3
Statement66	3.71	4.00	4.00	3.63	4.00	4.00	3.66	4.00	4.00		0.81	0.90	3	0.56	0.75	3	0.65	0.81	3
Statement67	4.19	4.00	4.00	3.91	4.00	4.00	4.02	4.00	4.00		0.26	0.51	2	0.60	0.78	3	0.48	0.69	3
Statement68	3.95	4.00	4.00	3.88	4.00	4.00	3.91	4.00	4.00		0.55	0.74	3	0.31	0.55	2	0.39	0.63	3

Table 4.13: Measures of Location and Spread on Information Technology Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement61	-1.17	0.89	-0.14	-0.03	-0.90	1.14
Statement62	-0.49	-0.27	-0.23	0.01	-0.36	-0.17
Statement63	-0.08	-0.47	-0.87	1.15	-0.43	0.23
Statement64	-0.31	-0.22	-0.59	0.38	-0.48	0.26
Statement65	0.37	-0.76	-0.89	-0.44	-0.40	-0.02
Statement66	-0.27	-0.47	-1.19	0.70	-0.66	0.08
Statement67	0.36	0.60	-1.15	1.85	-1.11	2.65
Statement68	-0.74	1.40	-0.08	0.40	-0.41	0.97

Table 4.14 Measures of Shape on Information Technology Maintenance Element as per survey

	Measures of Location SP			Measures of Location HM			Measures of Location HE				Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode		Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement69	4.05	4.00	4.00	3.63	4.00	4.00	3.79	4.00	4.00		0.65	0.80	3	0.95	0.98	4	0.86	0.93	4
Statement70	3.86	4.00	4.00	3.50	4.00	4.00	3.64	4.00	4.00		0.83	0.91	3	0.77	0.88	4	0.81	0.90	4
Statement71	3.86	4.00	4.00	3.56	4.00	4.00	3.68	4.00	4.00		0.63	0.79	3	0.51	0.72	3	0.57	0.75	3
Statement72	4.10	4.00	4.00	3.59	4.00	4.00	3.79	4.00	4.00		0.69	0.83	3	0.70	0.84	4	0.74	0.86	4
Statement73	3.71	4.00	4.00	3.50	4.00	4.00	3.58	4.00	4.00		0.51	0.72	3	0.71	0.84	4	0.63	0.80	4
Statement74	3.67	4.00	4.00	3.41	4.00	4.00	3.51	4.00	4.00		0.43	0.66	3	0.59	0.77	3	0.52	0.72	3
Statement75	4.10	4.00	4.00	3.75	4.00	4.00	3.89	4.00	4.00		0.29	0.54	2	0.32	0.57	3	0.33	0.58	3
Statement76	3.29	3.00	3.00	3.28	3.50	4.00	3.28	3.00	4.00		0.51	0.72	3	0.79	0.89	3	0.67	0.82	4
Statement77	3.43	4.00	4.00	3.59	4.00	4.00	3.53	4.00	4.00		0.96	0.98	4	0.64	0.80	3	0.75	0.87	4
Statement78	3.33	4.00	4.00	3.59	4.00	4.00	3.49	4.00	4.00		1.33	1.15	4	0.51	0.71	3	0.83	0.91	4
Statement79	3.67	4.00	4.00	3.56	4.00	4.00	3.60	4.00	4.00		0.73	0.86	3	0.58	0.76	3	0.63	0.79	3

Table 4.15: Measures of Location and Spread on Planning and Scheduling Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement69	-1.36	2.82	-0.93	0.61	-1.07	1.02
Statement70	-0.57	-0.12	-0.91	1.00	-0.69	0.47
Statement71	-1.06	1.62	-0.80	0.23	-0.78	0.47
Statement72	-1.34	2.52	-1.55	2.25	-1.26	1.85
Statement73	-0.40	0.51	-1.21	1.43	-1.01	1.38
Statement74	-0.69	0.89	-0.76	-0.12	-0.76	0.17
Statement75	0.11	0.94	-1.13	2.00	-0.63	1.86
Statement76	-1.39	4.01	-0.31	-1.16	-0.57	-0.10
Statement77	-1.37	2.17	-0.73	0.07	-1.10	1.38
Statement78	-0.73	-0.23	-0.35	0.12	-0.84	0.72
Statement79	-0.84	0.29	-0.93	0.17	-0.84	0.09
Statement80	0.36	0.60	-0.74	2.10	-0.57	2.09

Table 4.16 Measures of Shape on Planning and Scheduling Maintenance Element as per survey

- A mean value of 4.10 with a standard deviation of 0.54, has been achieved by Steelplant in support that adherence to statutory requirements are adhered to ensure plant integrity and safety (statement 75).
- A mean value of 4.19, with a standard deviation of 0.51, reveals that Steelplant personnel agree that all shutdowns are scheduled using either critical path or other graphical methods to show jobs, resources, time frames and sequences (statement 80).
- Planning and scheduling at the Hotmill needs to be driven, as the results from the survey indicate that the plant personnel are either not aware of planning and scheduling, or the practice is not effective.
- Planning and scheduling is a World Class/Best Practice maintenance practice and it is of utmost importance that the plant personnel focus on this practice, especially at the Hotmill, as this can restrict a maintenance operation from meeting its objectives and goals.

Figure 4.2 indicates that the maintenance maturity level for Material/spares management maintenance area at the Hot End of the business is currently 69.66%. This is above average and can improve somewhat when compared to a 100% benchmark (obtaining full score for all practices under this maintenance area). From tables 4.17 and 4.18, the Steelplant has scored high (mean = 4.29 with a standard deviation = 0.46) with majority plant personnel agreeing with the practice of having satellite/squirrel stores for commonly used items. However, one must be guarded against this as grounded theory on World Class practices suggests that squirreling of parts should be minimised. This is with a view to minimise poor use of the company's assets.

	Measures of Location SP			Measures of Location HM			Measures of Location HE			Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode	Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement81	3.19	3.00	3.00	3.31	3.00	3.00	3.26	3.00	3.00	0.66	0.81	3	0.42	0.64	2	0.51	0.71	3
Statement82	3.76	4.00	4.00	3.22	3.00	4.00	3.43	4.00	4.00	0.59	0.77	3	0.69	0.83	2	0.71	0.84	3
Statement83	4.29	4.00	4.00	3.59	4.00	4.00	3.87	4.00	4.00	0.21	0.46	1	0.83	0.91	4	0.69	0.83	4
Statement84	3.71	4.00	4.00	3.06	3.00	3.00	3.32	3.00	4.00	0.71	0.85	3	0.83	0.91	3	0.88	0.94	4
Statement85	3.95	4.00	4.00	3.69	4.00	4.00	3.79	4.00	4.00	0.55	0.74	3	0.54	0.74	3	0.55	0.74	3
Statement86	3.48	4.00	4.00	3.22	3.00	4.00	3.32	3.00	4.00	0.86	0.93	4	0.76	0.87	3	0.80	0.89	4
Statement87	3.57	4.00	4.00	3.16	3.00	3.00	3.32	3.50	4.00	0.76	0.87	3	0.66	0.82	3	0.71	0.84	3
Statement88	3.29	3.00	3.00	3.09	3.00	3.00	3.17	3.00	3.00	0.41	0.64	3	0.41	0.64	3	0.41	0.64	4
Statement89	3.86	4.00	4.00	3.44	3.00	3.00	3.60	4.00	4.00	0.53	0.73	3	0.45	0.67	3	0.51	0.72	3
Statement90	3.81	4.00	4.00	3.69	4.00	4.00	3.74	4.00	4.00	0.46	0.68	3	0.23	0.48	2	0.32	0.56	3

Table 4.17: Measures of Location and Spread on Material/Spares Management Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement81	-1.00	1.19	-0.39	-0.60	-0.77	0.64
Statement82	-1.01	1.34	-0.44	-1.41	-0.58	-0.72
Statement83	1.02	-1.06	-0.98	1.11	-1.20	2.33
Statement84	-0.48	0.05	-0.67	-0.33	-0.55	-0.05
Statement85	-0.74	1.40	-0.45	0.29	-0.52	0.40
Statement86	-0.75	1.42	-1.08	0.81	-0.86	0.88
Statement87	-0.49	-0.27	-0.13	-0.75	-0.23	-0.70
Statement88	0.91	1.51	-0.86	2.92	-0.17	2.48
Statement89	-0.63	1.13	-0.10	-0.10	-0.22	-0.05
Statement90	-0.81	1.71	-0.59	0.61	-0.73	1.58

Table 4.18 Measures of Shape on Material/Spares Management Maintenance Element as per survey

According to figure 4.2, the maintenance maturity management at the Hot End of the business indicates a level of 68.83% for Maintenance Process Re-engineering maintenance area. From tables 4.19 and 4.20, this is apparent as all mean value is indicative of either unawareness or an inefficient and/or ineffective implementation of these practices. It is necessary that maintenance costs, quality and time be measured and monitored to achieve World Class standards and in support of the organisations goals and production objectives.

	Measures of Location SP			Measures of Location HM			Measures of Location HE				Measures of Spread SP			Measures of Spread HM			Measures of Spread HE		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode		Variance	Std Dev	Range	Variance	Std Dev	Range	Variance	Std Dev	Range
Statement91	3.57	4.00	4.00	3.38	3.00	3.00	3.45	3.00	4.00		0.66	0.81	3	0.50	0.71	3	0.56	0.75	3
Statement92	3.76	4.00	4.00	3.34	3.00	3.00	3.51	4.00	4.00		0.39	0.62	3	0.49	0.70	3	0.49	0.70	3
Statement93	3.76	4.00	4.00	3.22	3.00	3.00	3.43	3.00	3.00		0.49	0.70	2	0.63	0.79	3	0.63	0.80	4
Statement94	3.52	4.00	4.00	3.13	3.00	3.00	3.28	3.00	3.00		0.66	0.81	3	0.50	0.71	3	0.59	0.77	4
Statement95	3.57	4.00	4.00	3.50	4.00	4.00	3.53	4.00	4.00		0.76	0.87	3	0.52	0.72	3	0.60	0.77	4

Table 4.19: Measures of Location and Spread on Maintenance Process Re-engineering Maintenance Element as per survey

	Measures of Shape SP		Measures of Shape HM		Measures of Shape HE	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Statement91	-0.25	-0.13	-0.11	-0.19	-0.12	-0.26
Statement92	-1.16	2.42	0.00	-0.10	-0.39	-0.11
Statement93	0.37	-0.76	-1.25	2.16	-0.72	1.94
Statement94	-0.08	-0.22	-0.77	1.46	-0.28	0.71
Statement95	-0.49	-0.27	-1.67	3.45	-1.00	1.30

Table 4.20 Measures of Shape on Maintenance Process Re-engineering Maintenance Element as per survey

4.8 Chapter Summary

According to figure 4.3, theoretically, the following gaps exist between World Class/Best Practice Maintenance Practices and the CSCMS and Plant-Specific Maintenance Practices:

The CSCMS fully supports 11 out of the 14 World Class/Best Practice Maintenance Practices. This means that there is a gap of 21.43% between the CSCMS and World Class/Best Practice Maintenance Practices

The HMMP fully supports 10 out of the 14 World Class/Best Practice Maintenance Practices. This means that there is a gap of 28.57% between the HMMP and World Class/Best Practice Maintenance Practices

The SPMP fully supports 9 out of the 14 World Class/Best Practice Maintenance Practices. This means that there is a gap of 35.71% between the SPMP and World Class/Best Practice Maintenance Practices

According to figure 4.4, theoretically, the following gaps exist between the Plant-Specific Maintenance Practices and CSCMS:

The HMMP fully supports 11 out of the 14 Maintenance Practices. This means that there is a gap of 21.43% between the HMMP and CSCMS

The SPMP fully supports 8 out of the 14 Maintenance Practices. This means that there is a gap of 42.86% between the SPMP and the CSCMS.

The results from the maintenance management maturity survey indicate that the Steelplant is at a Level 4 (73.66%) – Wisdom Level, the Hotmill is at a Level 3 (68.33%) – Accept/Understanding Level, and the overall Hot End of the organisation is at a level 4(70.44%) – Wisdom level.

Gap Analysis between World Class/Best Practice Maintenance Practices and the CSCMS and Plant-Specific Maintenance Practices			
World Class/Best Practice Maintenance Practice	**CSCMS**	**HMMP**	**SPMP**
1. Scope and Purpose - Leadership and Policy Development	There are no vision and mission statements that support Columbus Stainless's directions and goals in this Maintenance Strategy.	There is no clear mission and vision supportive of the organisation's direction and goals.	A maintenance plan is non-existent; hence there are no vision and mission statements that support Columbus Stainless's directions and goals in this Maintenance Strategy.
2.Maintenance Organisation	Conforms to World Class/Best Practice maintenance Practice.	Organisation structure in place.	Organisation structure in place.
3. RCM	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	RCM is not driven
4.Spares Management/Inventory Control	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	The allocation of stores item codes on all maintenance spares still has to be completed.
5. Measurement Control of Equipment and Processes	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice
6. Lifecycle Management	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice
7. Information	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice
8. 1st Line Maintenance	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice
9.Developing People and Training	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice

World Class/Best Practice Maintenance Practice	CSCMS	HMMP	SPMP
10. Continuous Improvement	Although, as the CSCMS states that the QS9000 quality principles should be incorporated, the CSCMS does not emphasise that all the continuous improvement techniques should be linked to improving quality. Also the PDCA cycle should be included as part of the continuous improvement process.	The HMMP states that the QS9000 quality principles should be incorporated, but it does not emphasise that all the continuous improvement techniques should be linked to improving quality or as per the Hotmill Quality Plan. This should be included in this HMMP to instil awareness of the Hotmill Quality Plan. Also the PDCA cycle should be included as part of the continuous improvement process.	The SPMP should include in its maintenance plan, the PDCA cycle as part of the continuous improvement process. Also, it should be stated that continuous improvement techniques should be linked to the Quality Management System
11. Quality Management System	The new accreditation to ISO 9001:2000 Quality Management System should be included for adoption by all plants and personnel.	The new accreditation to ISO 9001:2000 Quality Management System should be included for adoption by all plants and personnel.	The new accreditation to ISO 9001:2000 Quality Management System should be included for adoption by all plants and personnel.
12. Financial Control	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice
13. Planning and Scheduling	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice	Conforms to World Class/Best Practice maintenance Practice
14. Work Flow with work order	There is a gap with the CSCMS in that although this is performed in each plant, there is no stipulation of this maintenance practice in the CSCMS. This should be included in the CSCMS as it gives a clear indication that the organisation should move towards becoming a World Class Maintenance Organisation.	This should also be included in the HMMP as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.	This should also be included in the SPMP as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.

Figure 4.3: Gap Analysis between World Class/Best Practice Maintenance Practices and CSCMS and Plant-Specific Practices.

Gap Analysis between the CSCMS and the Plant-Specific Maintenance Practices		
CSCMS	**HMMP**	**SPMP**
1. Scope and Purpose - Leadership and Policy Development	This is not readily apparent, as the following is not mentioned: • Support for the CSCMS. • There is no clear mission and vision supportive of the organisation's direction and goals.	This is not readily apparent, as the following is not mentioned: • Support for the CSCMS. • There is no clear mission and vision supportive of the organisation's direction and goals.
2.Maintenance Organisation/Structure	Organisation structure in place.	Organisation structure in place.
3. RCM	Supports CSCMS.	RCM is not driven
4.Spares Management/Inventory Control	Supports CSCMS.	The allocation of stores item codes on all maintenance spares still has to be completed. Also has to optimise certain spares management practices
5. Measurement Control of Equipment and Processes	Supports CSCMS.	Supports CSCMS.
6. Lifecycle Management	Supports CSCMS.	Supports CSCMS.
7. Information	Supports CSCMS.	Supports CSCMS.
8. 1st Line Maintenance	Supports CSCMS.	Supports CSCMS.
9.Developing People and Training	Supports CSCMS.	The SPMP conforms to only 58% of the training courses identified in the CSCMS.
10. Continuous Improvement	Supports CSCMS.	Supports CSCMS.
11. Quality Management System	The new accreditation and adherence to ISO 9001:2000 Quality Management System should be included for adoption by all plant personnel.	The new accreditation and adherence to ISO 9001:2000 Quality Management System should be included for adoption by all plant personnel.
12. Financial Control	Supports CSCMS.	Supports CSCMS.
13. Planning and Scheduling	Supports CSCMS.	Supports CSCMS.
14. Work Flow	This should also be included in the HMMP as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.	This should also be included in the SPMP as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.

Figure 4.4: Gap Analysis between the CSCMS and the Plant-Specific Maintenance Practices.

Chapter 5: Conclusions and Recommendations

5.1 Introduction

This chapter concludes the study and includes recommendations on improving the gaps found between World Class/Best Practice maintenance practices and the CSCMS and Plant-Specific maintenance strategies, and also between the CSCMS and plant-specific maintenance plans.

5.2 Conclusions developed from the theoretical analysis and the maintenance management survey

According to the maintenance management maturity survey, the Steelplant is currently at an overall 73.66% maturity level (figure 4.2). This means that the maintenance activities practiced at the Steelplant is of such a calibre, that it is placed on level 4 in terms of the maintenance management maturity level (see figure 4.1). This Level 4 – Wisdom Level, indicates that continuous improvement is practiced widely, there is use of World Class/Best Practice techniques, and reliable and accurate information is available. There is an indication that all Steelplant personnel are committed to quality maintenance as a routine part of their operational philosophy. This, however, is not in line with the theoretical gap analysis performed, which indicates that there are a few more gaps to be filled in order to become a World Class organisation. The SPMP fully supports 9 out of the 14 World Class/Best Practice Maintenance Practices. It can only be assumed that although the Steelplant has no documented maintenance plan that supports the CSCMS, the maintenance activities and methodologies practiced are close to World Class/Best Practice standards, even though a theoretical analysis does not prove this.

From the results that has been obtained on the floor, there is clear indication that many efforts are driven at the Steelplant in order to focus on all processes and actions necessary to ensure optimal machine functionality – which includes availability, reliability, accuracy of operation and safety - to ensure that maintenance supports and sustains the Columbus Stainless

Manufacturing Plan, which entails maximisation of volumes and low cost production.

The SPMP fully supports 8 out of the 14 Maintenance Practices contained in the CSCMS. This means that there is a gap of 42.86% between the SPMP and the CSCMS. There is thus a breakdown of synergy between the CSCMS and the Steelplant maintenance strategy. This can be attributed mainly to the non-existence of a plant-specific maintenance plan, and total reliance on management and maintenance crew at the Steelplant for maintenance guidelines. By developing and implementing an integrated maintenance strategy, the gaps between the CSCMS and the SPMP identified can be closed, and synergy established.

The Hotmill has achieved an overall 68.33% maintenance maturity level (figure 4.2). This places the Hotmill at a level 3 in terms of the maintenance management maturity level (see figure 4.1). This level 3 - Acceptance/Understanding Level indicates that the Hotmill plant personnel accept/understand that reactive maintenance is wrong, and they only now can begin to identify and solve problems. The theoretical evaluation, however, does not show that this is true. From the gap analysis, it is apparent that the HMMP fully supports 10 out of the 14 World Class/Best Practice Maintenance Practices. It can be assumed that even though the Hotmill has a maintenance plan in place, the plant personnel are not implementing this plan fully, or the plant personnel are aware of the standards for obtaining a World Class maintenance organisation, and have to exert much more effort to attain this.

From the results that has been obtained on the floor, there is an indication that strategy is apparent, but there is no clear focus and as a result strategy deployment is lacking to ensure optimal machine functionality – which includes availability, reliability, accuracy of operation and safety - to ensure that maintenance supports and sustains the Columbus Stainless Manufacturing Plan, which entails maximisation of volumes and low cost production.

From the evaluation of the CSCMS and plant-specific maintenance strategies, the HMMP fully supports 11 out of the 14 Maintenance Practices contained in the CSCMS. This means that there is a gap of 21.43% between the HMMP and CSCMS. This means that there is evidence of synergy between the CSCMS and the HMMP, and with focus on the three gaps identified, 100% synergy can be achieved.

The overall maintenance management maturity level is 70.44% at the Hot End of Columbus Stainless, which is at a level 4 - Wisdom Level. This is an indication that, on average, the Hot End of the business has senior management commitment, continuous improvement is extensive, and there is evidence of the use of World Class/Best Practice maintenance practice. There is a lot of improvement required in a few areas that will need focus in order to be a World Class maintenance organisation. Based on this result, the maintenance practices at the Hot End of the business is able to support the Columbus Stainless Manufacturing Plan.

The theoretical gap analysis indicates that the CSCMS fully supports 11 out of the 14 World Class/Best Practice Maintenance Practices identified in grounded theory. This is an indication that with a little focus on the gaps identified, the CSCMS will incorporate World Class standards. If all plants are support this CSCMS, then Columbus Stainless will be recognised as a World Class maintenance organisation and have a sustainable competitive advantage over all competitors. A conclusion can be drawn that the CSCMS currently available is able to support and sustain the Columbus Stainless Manufacturing Plan.

5.3 Recommendations

- The PDCA (Plan Do Check Act) cycle is the sequence of activities, which are undertaken on a cyclical basis to improve activities. This continuous improvement technique should be included as part of the continuous improvement process in the CSCMS and all Plant-Specific maintenance plans so that it can be driven down to all personnel.

- The new accreditation to ISO 9001:2000 Quality Management System should be included in the CSCMS. In the light of this, being a corporate strategy document, this new practice should be included for adoption by all plants and personnel. The plants will then support the CSCMS and include this in their own maintenance plans.
- There is a gap with Work Flow by means of a work order maintenance practice in the CSCMS and plant-specific maintenance plans, in that although this is performed in each plant, there is no stipulation of this maintenance practice in the strategies. This should be included in the CSCMS and plant-specific maintenance plans, as it gives a clear indication that the organisation should move towards becoming a World Class Maintenance Organisation. This should also be included as it is an integral part of an effective maintenance operation, and it serves to identify, request, prioritise, schedule, activate, track, and analyse work. This document allows the control and monitoring of all work activities to identify costs, losses and trending of problems.
- Vision and mission statements that support Columbus Stainless's directions and goals in the Maintenance Strategy should be developed and included both in the CSCMS and all Plant-Specific maintenance strategies. The mission statement will spell out exactly "who we are and what we do", and the vision statement will fulfil "where we are going" with all relevant maintenance strategies. The plant-specific maintenance strategies must also mention support of the CSCMS.
- No organisation can plan in detail every aspect of its current or future actions, but all organisations can benefit from some idea of where they are heading and how they could get there. Put another way, all organisations need some strategic direction. It is just the same with the maintenance function. It is highly recommended that by developing and implementing an integrated maintenance strategy at the Steelplant, the gaps between the CSCMS and the SPMP identified can be closed, and synergy established. This can be achieved very easily by running focus groups within the Steelplant, led by either a facilitator from the Central Engineering Services Department or a maintenance

manager with in-depth knowledge of the maintenance practices contained in the CSCMS, objectives and goals as contained in the Manufacturing Plan, and current maintenance practices. This document can be used as a guideline where the gaps have already been identified and can be improved on.

- RCM is a Best Practice maintenance methodology, and it is recommended that the Steelplant adopt and drive the principles under this methodology.
- The spares management/inventory control at the Steelplant can be greatly improved if allocation of stores item codes on all maintenance spares is optimised.
- The Steelplant conforms to only 58% of the training courses identified in the CSCMS. This gap should be filled and addressed in the development of its own maintenance plan. Particular attention must be paid to personnel's capabilities, training needs and development to ensure that their commitment and skills can be recognised and developed to the full benefit of the production and maintenance organisation.
- Organisational efficiency is apparent at both plants, however, focus needs to be reaffirmed as results from the shop floor indicate that the ratios between supervisors and maintenance workers are not optimised.
- Planning and scheduling at the Hotmill needs to be driven, as the results from the survey indicate that the plant personnel are either not aware of planning and scheduling, or the practice is not effective. Planning and scheduling is a World Class/Best Practice maintenance practice and it is of utmost importance that the plant personnel focus on this practice, especially at the Hotmill, as this can restrict a maintenance operation from meeting its objectives and goals.
- It is apparent that satellite stores are useful with spares management tactics. However, attention needs to be paid to this as grounded theory on World Class practices suggests that squirreling of parts should be minimised. This is with a view to minimise poor use of the company's

assets. All major spares should be allocated stock items, and control of spares can be optimised, and better control of maintenance costs can be achieved.

- Maintenance costs, quality and time should be measured and monitored to achieve World Class standards and in support of the organisations goals and production objectives.
- In general, although the HMMP is in place and is very detailed, the results obtained from the Hotmill personnel by means of the management survey, indicate that there is either a great deal of unawareness of the HMMP, or the plan is not executed effectively. Focus groups should be held in the Hotmill to discuss and identify areas that require more focus. The possibilities of training/retraining of procedures as identified in the HMMP should be looked at strongly.
- In the light of the non-existence of a maintenance plan, and a big gap analysis between the Steelplant and World Class/Best Practice maintenance practices and the CSCMS, a reflection of this is not apparent from the plant personnel by means of the maintenance management survey. It is highly recommended that a secondary study be performed to test the reliability, accuracy and correlation of these results against maintenance costs, planned to unplanned work activities, availabilities of equipment, delays, breakdowns, plant performance, etc. This is with a view that an acceptance will be received that the maintenance practices at the Steelplant are according to World Class/Best Practice standards and all associated recommendations will be completely ignored, or the focus on maintenance practices at the Steelplant will be removed and no continuous improvement will take place. It is of utmost importance to remove any resulting complacency and focus on the Hot End of the organisation so that maximisation of volumes here can be supported and sustained, and increase volumes at the cold end of the business.
- Lastly it is highly recommended that all the World Class/Best Practice maintenance practices that is implemented, should be measured to see how well they perform in an organisation, and how well the

maintenance strategy enables the rest of the organisation to meet its goals and objectives.

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5.4 Chapter Summary

The conclusions developed from the theoretical analysis and the maintenance management survey show that the objectives of this study have been met. The CSCMS available is able to support the Columbus Stainless Manufacturing Plan, and hence be able to sustain the maximisation of volumes and low cost leadership strategy. There is a breakdown in synergy between the Steelplant maintenance strategy and the CSCMS, which is mainly attributable to the non-existence of a maintenance plan. The synergy between the CSCMS and the Hotmill maintenance strategy is apparent, however, deployment of the strategy in the Hotmill is lacking. Many recommendations are suggested to optimise maintenance practices with a view to becoming a World Class Maintenance Organisation.

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Appendix 1: Maintenance Management Questionnaire

TO: Respondent

FROM: Arvin Bipath, C & I - Hotmill

CC:

DATE: 19th August 2003

Subject: Study on Maintenance Management

Sir/Madam

Please find attached a questionnaire/s surveying how you view the maintenance management in your section. This document/s has been sent to plant personnel at the Steelplant and Hotmill plants. The results will be used to determine the various maintenance practices adopted at the Hot End of the business. These results will be used to assist me in completing a study on maintenance strategies, and can also be used for strategic decision-making. Your honesty and support will be highly appreciated.

You can request the results of this survey, if required, via the Engineering Systems Department (J Myburgh). All respondent names will be withheld and the responses will be treated with the utmost confidence.

I thank you for your time and look forward to your response. It would be appreciated if you would return the questionnaire to me before 29th August 2003.

Yours Sincerely

A.Bipath

MAINTENANCE MANAGEMENT QUESTIONAIRE

INSTRUCTIONS:

Award each of the following statements a score depending on how well your maintenance management adheres to the statement. Award your score for each statement based on how much you agree or disagree with the statement, using the following scores:

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
5	4	3	2	1

First, please give us details about yourself:

I describe my role as (please check only one):

Management	Supervisory	Artisan/Technician	Administrative

In which plant do you work?

Plant: ______________________

In which section/department do you work?

Maintenance	Operations/Production	IT/Services Support	Other

	Area / Statement	Score
Statement No.	**Maintenance Strategy**	
1	All plant personnel are aware of the Columbus Stainless Corporate Maintenance Strategy.	
2	We have a defined long term maintenance plan or strategy to guide maintenance improvement efforts that supports, and is linked to, the Columbus Stainless Corporate Maintenance Strategy.	
3	The maintenance department has a defined mission, mandate and set of objectives that are well understood by all personnel involved.	
4	All plant personnel are aware the role of maintenance in achieving the company's objectives and goals as set out in the company's Five-year Business Plan.	
5	All plant personnel have been briefed on the way that maintenance is requested and organised.	
6	All plant personnel understand the maintenance systems and procedures.	
7	Production people understand the maintenance needs of their equipment.	
8	Cooperation between production and maintenance is evident at all levels.	
9	Production participates in developing the maintenance programme and major future work, like shutdowns.	
10	Annual maintenance budget is prepared based on a long-term improvement plan, scheduled overhaul strategy and historical equipment performance. The maintenance effort is related to the expected performance of the equipment and indications are provided as to the likely outcome if work is to be deferred.	
11	Our approach to maintenance is proactive, i.e. when something breaks we fix it, but usually we are able to catch the breakdowns before they occur.	
	Total (Not necessary to add scores)	

	Area / Statement	Score
Statement No.	**Organisation / Human Resources**	
12	All plant personnel are aware of the organisational structure.	
13	Our organisational structure enhances communications and interaction.	
14	Our organisational structure encourages efficiency.	
15	Functions covering plant needs are fully defined, and our employees understand what is / is not expected of them.	
16	Maintenance staffing level is adequate, highly capable/skilled and experienced.	
17	The maintenance organisation is mostly decentralised and	

	organised by area or product line.	
18	First line supervisors are responsible for at least 12 to 15 maintenance workers.	
19	Overtime represent less than 5% of the total annual maintenance man-hours. Overtime is not concentrated all in one trade group or area, but it is well distributed.	
20	Contractors are used to assist plant staff during shutdowns and / or for specific projects or specialised jobs. Their cost / benefit is periodically reviewed.	
21	A formal, established apprenticeship program is employed to address the maintenance department's needs for qualified trades, with clear standards for completion.	
22	People are developed through regular maintenance training programs.	
23	Maintenance supervisors have also received formal supervisory training.	
24	Adequate support staff is available to allow supervisors to spend more than 75% of their time in direct support of their people.	
	Total (Not necessary to add scores)	

	Area / Statement	**Score**
Statement No.	**Employee Empowerment**	
25	Continuous improvement teams are in place and active.	
26	Self-directed work teams of operators, maintainers and engineers perform much of the work.	
27	Multi-skilled trades people (e.g. electrician mechanics, mechanic electricians, instrument electricians) are a key feature of the organisation.	
28	Operators understand the equipment they run, perform minor maintenance activities like cleaning, lubricating, minor adjustments, inspections and minor repairs (not generally requiring the use of tools) – autonomous maintenance is practiced.	
29	Partnerships have been establishes with key suppliers and contractors; risk sharing (distribution of risk) is a feature of these arrangements.	
30	Supervisors regularly discuss performance and costs with their work teams.	
31	Operations can get needed support from maintenance trades after hours quickly and with a minimum of effort.	
32	Call-outs are performed by an on-shift maintainer who decides which support is needed without reference to a supervisor for guidance. Operations do not decide who will be called.	
33	Maintenance is part of the team involved during design and commissioning of new modifications or capital additions to the	

	plant.	
34	We do not have a "Command and Control" organisation with highly disciplined procedures.	
	Total (Not necessary to add scores)	

	Area / Statement	**Score**
Statement No.	**Maintenance Tactics**	
35	Plant management and operations support predictive and preventative maintenance.	
36	Preventative and / or predictive maintenance represents 60% or more of the total maintenance man-hours.	
37	We used a formal reliability based program for determining the correct Planned Maintenance (PM) routines to perform. The program is still used for continuously fine-tuning and improving our PM performance.	
38	For new equipment we review the manufacturer's maintenance recommendations and revise them as appropriate for our unique operating environment and demands.	
39	Condition based maintenance is favoured over time or cycle based maintenance.	
40	Use of condition based maintenance techniques such as vibration analysis, oil sampling, NDT and performance monitoring is widespread.	
41	Results from PM inspections and failure history data are used to continually refine and improve effectiveness of the PM process.	
42	Compliance with the PM program is high: 95% or more of the PM work is completed as scheduled.	
43	Less than 5% of the total maintenance work man-hours are devoted to emergencies (e.g. plant shutdowns).	
	Total (Not necessary to add scores)	

	Area / Statement	**Score**
Statement No.	**Reliability Analysis**	
44	Overall Equipment Effectiveness (OEE) is used to identify and attack the major losses caused by equipment.	
45	Equipment history is maintained for all key pieces of equipment showing cause of failure and repair work completed.	
46	Frequent failures are analysed to determine root cause and prescribe preventive measures – Root Cause and Failure Analysis (RCFA) is performed frequently.	
47	Our failure prediction and/or prevention efforts are successful. We can usually eliminate the problems we focus on without creating new problems.	
48	Equipment Mean Time Between Failures (MTBF) and process	

	or mechanical availability are calculated and forecasted.	
49	Value risk studies have been conducted to optimise maintenance programs.	
50	All equipment has been classified based on it importance to plant operations and safety. The classification is used to help determine work order priorities and to direct engineering resources. We work on the most critical equipment's problems first.	
51	Reliability statistics are maintained even though our employees have a good feel for the best and worst equipment.	
52	Reliability Centred Maintenance (RCM), Total Productive Maintenance (TPM) or other formal analysis is used to determine the optimum maintenance routines to perform on our equipment.	
	Total (Not necessary to add scores)	

	Area / Statement	**Score**
Statement No.	**Performance Measures / Benchmarking**	
53	Labour and material costs are accumulated and reported against key systems and equipment.	
54	Downtime records including cause are kept on key equipment and systems.	
55	The maintenance department has a set of performance indicators that are routinely measured and tracked to monitor results relative to the maintenance strategy and improvement process.	
56	All maintenance staff has been trained in or taught the significance of the measures we use. Most of us can read the measures and trends and can determine whether we are improving our overall performance or not.	
57	All maintenance trades / areas can see and understand the relationship between their work and results of the department overall. If a particular trade / area is weak they can see it and work to correct it.	
58	Performance measures are published or posted regularly and kept available / visible for all department staff and trades to see and read.	
59	Internal and / or industry norms are used for comparison.	
60	Maintenance performance of "best in class" organisation has been benchmarked and used to set targets for performance indicators.	
	Total (Not necessary to add scores)	

	Area / Statement	Score
Statement No.	**Information Technology**	
61	A fully functional maintenance management system exists which is linked to the plant financial and material management systems.	
62	Our maintenance and materials management information is considered to be a valuable asset and is used regularly. The system is not just a "black hole" for information or a burden to use, which produces no benefit.	
63	Expert systems are used in areas where complex diagnostics are required.	
64	Our maintenance management system is easy to use. Most of the maintenance department, especially supervisors and trades, have been trained on it, can use it and do use it.	
65	Condition based maintenance techniques are supported by automated programs for data analysis and forecasting.	
66	Parts information is easily accessible and linked to equipment records. Finding parts for specific equipment is easy to do and the stock records are usually accurate.	
67	Scheduling for major shutdowns is done using a project management system that determines critical path and required levels of resources.	
68	Our planners/schedulers use the maintenance management system to plant jobs and to select and reserve spare parts and materials.	
	Total (Not necessary to add scores)	

	Area / Statement	Score
Statement No.	**Planning and Scheduling**	
69	Over 90% of maintenance work is covered by a standard written work order, standing work order, PM work order, a PM checklist or routine.	
70	Over 80% of maintenance work (preventative, predictive and corrective) is formally planned by a planner, a supervisor or other person at least 24 hours or more before being assigned to the trades.	
71	A plant equipment register exists which lists all equipment in the plant that requires some form of maintenance or Engineering support during its life.	
72	All non-emergency work requests are screened, estimated and planned (with tasks, materials and tools identified and planned) by a dedicated planner.	
73	A priority system is in use for all work requests / orders. Priorities are set using pre-defined criteria that are not abused to circumvent the system.	
74	Work for the week is scheduled in consultation with production	

	and is based on balancing work priorities set by production with the net capacity of each trade taking into account emergency work and PM work.	
75	Adherence to statutory requirements to ensure plant integrity and safety.	
76	Work backlog is measure and forecasted for each trade and is managed at less than 3 weeks per trade.	
77	Planning for the utilisation of maintenance resources to ensure a cost effective maintenance.	
78	Long term plans (1 - 5 years) are used to forecast major shutdowns and maintenance work and are used to prepare the maintenance budget.	
79	Realistic assessments of jobs are used to set standard times for repetitive tasks and to help schedule resources.	
80	All shutdowns are scheduled using either critical path or other graphical methods to show jobs, resources, time frames and sequences.	
	Total (Not necessary to add scores)	

	Area / Statement	**Score**
Statement No.	**Material/Spares Management**	
81	Service levels are measured and are usually high. Stockouts represent less than 3% of orders placed at the storeroom.	
82	Spares and materials are readily available for use when needed.	
83	Distributed (satellite) stores are used throughout the plant for commonly used items (e.g. fasteners, fittings, common electrical parts).	
84	Parts and materials are restocked automatically before the inventory on hand runs out and without prompting by the maintenance crews.	
85	A central tool crib is used for special tools.	
86	Inventory is reviewed on a regular basis to delete obsolete or very infrequently used items. An ABC analysis is performed monthly.	
87	Purchasing/Stores is able to source and acquire rush emergency parts that are not stocked quickly and with sufficient time to avoid plant downtime.	
88	Average inventory turnovers are greater than 1.5 times.	
89	Order points and quantities are based on lead-time, safety stock and economic order quantities.	
90	Inventory is controlled using a computerised system that is fully integrated with the maintenance management/planning systems.	
	Total (Not necessary to add scores)	

	Area / Statement	Score
Statement No.	**Maintenance Process Re-engineering**	
91	Key maintenance processes, e.g. planning, corrective maintenance, have been identified, and "as is" processes are mapped. Those maps are accurate reflections of the processes that are actually followed.	
92	Key maintenance processes are redesigned to reduce or eliminate non-value added activities.	
93	The CMMS and/or other management systems are used to automate work flow processes.	
94	Process mapping and redesign have been extended to administration and technical support processes.	
95	Maintenance process costs, quality and time are routinely measured and monitored. Activity costs are known.	
	Total (Not necessary to add scores)	
	Grand Total (Not necessary to add scores)	

MAINTENANCE MANAGEMENT QUESTIONAIRE

TO: Arvin Bipath, Hotmill C & I (bipath.arvin@columbus.co.za)
Tel no: x2902/7243

FROM:

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AREA:

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DATE:

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