

**ASSET MANAGEMENT AUDITING – THE ROADMAP TO ASSET  
MANAGEMENT EXCELLENCE**

by

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## **SUMMARY**

### **ASSET MANAGEMENT AUDITING – THE ROADMAP TO ASSET MANAGEMENT EXCELLENCE**

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Asset Management (AM) as a concept evolved from Maintenance Management to provide a more holistic approach to managing the life of a physical asset. The maturity of an organisation in its Asset Management practices and processes can be determined through applying an Asset Management Audit. This study had as main objective to develop an asset management auditing methodology. The methodology includes the development of a Program for Asset Management Improvement (PAMI) and the application of Business Process Engineering as a tool to realise the improvement opportunities identified through the audit. Asset Management is clearly defined in this study and a framework representing the scope of Asset Management developed to comprehensively address the relevant elements. The life cycle of an asset consists of the acquisition, operation, maintenance and disposal phases. These four phases of an asset's life represents the high level framework for Asset Management. The application of an asset management audit, according to the developed methodology, can create the "roadmap" to Asset Management excellence. By optimising the performance of asset management practices and processes a positive contribution can be made to the profitability or success of any organisation.

## Table of Contents

	Pg
Preliminaries	1
Chapter 1:	
Introduction/Background	7
1.1 Introduction	
1.2 Historical development and current state	
1.3 Research problem	
1.4 Research objectives	
Chapter 2:	
Literature Review/ Theoretical Background	10
2.1 Literature review	
2.2 Current methods and models	
2.2.1 Definition of Asset Management	
2.2.2 Current AM frameworks/models	
2.2.3 Current audit methodologies	
2.2.4 Asset Management improvement	
2.2.5 Business Process Engineering	
2.3 Need for improved method and model	
Chapter 3:	
Theoretical Framework / Conceptual Model	34
3.0 Introduction	
3.1 Asset Management defined	
3.2 Asset Management framework	
3.2.1 Asset Acquisition	
3.2.2 Asset Operation and Maintenance	
3.2.3 Asset Disposal	
3.3 Asset Management Auditing Methodology	
3.4 The “Roadmap” to Asset Management Excellence	

	3.5 Hypotheses	
Chapter 4:	Research Design and Methodology	54
	4.1 Research Strategy	
	4.1.1 Theory building research	
	4.1.2 Theory testing research	
	4.1.3 Theory application research	
	4.2 Research methodology	
	4.3 Research instruments	
Chapter 5:	Results: Data gathered and analysis	57
	5.1 Data gathering process	
	5.1.1 Practical application	
	5.1.2 Survey	
	5.2 Data or Information gathered	
	5.2.1 Practical application	
	5.2.2 Survey	
	5.3 Data analysis	
	5.3.1 Practical application	
	5.3.2 Survey	
	5.4 Hypotheses testing	
Chapter 6:	Conclusions and Recommendations	69
	6.1 Research results	
	6.2 Implications and/or contributions to theory/practice	
	6.3 Self Assessment	
	6.4 Recommendations	
	List of References and Appendices	72

## List of tables/figures

- Figure 1 - Asset Management Process [5]
- Figure 2 - Total Asset Management framework [2]
- Figure 3 - Asset Management Processes – The Big picture [1]
- Figure 4 - Asset Life Cycle Management Model [8]
- Figure 5 - Maintenance “Innocence-to-Excellence” evaluation [5]
- Figure 6 - Audit results on Bell-Mason type spider diagram [6]
- Figure 7 - AMiP Growth Model [11]
- Figure 8 - Stages of Excellence in Maintenance Management [13]
- Figure 9 - Process Reengineering Life Cycle [22]
- Figure 10 - High-level framework/model for Asset Management
- Figure 11 - Asset Acquisition framework/model
- Figure 12 - Asset Operation & Maintenance framework/model
- Figure 13 - Asset Disposal framework/model
- Figure 14 - Asset Management Audit methodology
- Figure 15 - Five Levels of Maturity for Business Processes in AM
- Figure 16 - Five Levels of Maturity for Performance Measures in AM
- Figure 17 - Typical Business Processes within the elements
- Figure 18 - Performance Measures Results
- Figure 19 - Business Process Assessment results

## **CHAPTER 1: INTRODUCTION AND BACKGROUND**

### **1.1 Introduction**

Asset Management (AM) as a concept evolved from Maintenance Management to provide a more holistic approach to managing the life of a physical asset. Asset Management (AM) in organizations today has become the focal point to improve and optimize the contribution of a physical asset to the overall success and prosperity of such organizations.

In order to achieve optimum return on investment from an asset and maximise their contribution to the revenue or success of an organization, the organization needs to grow their maturity in asset management. Woodhouse [1] postulates that many organizations have recognized that in spite of all the different initiatives like cost-cutting, re-organization, new technology, productivity and quality improvements, the picture is fragmented. Inefficiency, conflicting objectives, lack of coordination and missed opportunities are still plentiful.

According to the NSW Government [2] the application of a Total Asset Management process has taken agencies from simply acquiring and maintaining assets to a more strategic planning approach. This included the development of their annual Asset Strategy, followed by the Capital investment, Asset maintenance and Asset disposal strategic plans.

This means that, taking into consideration the stages in an asset's life-cycle, maturity levels has to be defined. An assessment or audit will have to be administrated to map the level of maturity of the organization's current practices and processes. Kaiser [3] says that management audits provide a framework for organizations to systematically review, analyze and recommend improvements in performance. Its purpose is also to ensure that management is carrying out its mission, meeting its goals and objectives, following proper procedures and managing resources effectively and efficiently.

### **1.2 Historical Development and Current State of AM Auditing**

Traditional asset or maintenance management audits are conducted through interviewing key role players in the organisation with a standard list of questions, performing walk-about and studying some requested documents and key measures. The results of such audits are then given in the form of a score with areas of concern highlighted. In most instances external

consultants are used and involvement in the corrective action development and implementation is limited. Currently some consultants have introduced software programs to assist in the administration of an asset management audit. Software programs are used in a workshop format where all the role players are brought together and the current level of maturity of the organization is mapped. A predetermined framework with maturity levels, developed by the consultants, is used to establish the current level of maturity for the organization. Results are used to decide on the appropriate improvement actions and in some instances a formal improvement plan are drawn up in a project format with accountabilities and due dates. Coetzee [4] postulates that measurement as part of the maintenance cycle consists of regular (typically annual) maintenance audits and a maintenance performance measurement process (typically performed monthly). The audit has as its objective to determine how well the processes succeed in achieving the results envisaged by management in setting up the maintenance policies and procedures.

### **1.3 Research Problem**

Asset Management has been given different definitions. Different entities and institutions define the scope for AM in various ways. A consolidation of the different views and opinions has to be done to formulate an acceptable definition for AM. Furthermore, the framework for AM has yet to be fully developed. Various organizations and agencies have developed frameworks which are not fully comprehensive and do not take into consideration all issues in the concept of Asset Management. Within the elements, of such a model or framework, the basic business processes needed has not been formally identified with their desired attributes. A best practice methodology to conduct AM Audits need to be formulated in order to map the current performance or maturity of an organization. Included in this methodology should be the improvement process after such an audit. This research will investigate methods and models to formulate and conduct such asset management audits through considering the whole life-cycle of physical assets.

### **1.4 Research Objectives**

The main objective of the research is to develop an Asset Management Auditing methodology or process.



Other objectives supporting the main objective include

- Asset Management to be clearly defined.
- A comprehensive, all-inclusive framework or model for Asset Management to be researched.
- Typical business processes and issues to address in each element of the framework to be shortly described.
- A best practice process for developing an asset management improvement strategy and program will be researched.

The desired theory should consolidate the available frameworks and elements in AM as well as instituting new elements if necessary. The evaluation of the underlying theory and validation or development of new methods and models will support the optimization of the principles of AM. By doing so, provide a world class or “best practice” AM auditing methodology. It is expected that the final theory, method or model will be practical, implementable and logical. Most organizations that invested in physical assets should be able to apply it to their businesses. It should provide a guideline to mature an organization to its desired or best practice level in Asset Management.

## CHAPTER 2: LITERATURE REVIEW AND THEORY

### 2.1 Literature review

A discussion of current theory and models relating to the objectives of this study and the field of Asset Management is summarized and presented in this Chapter. The chapter is divided into the various issues that have been researched. The following sub-topics are included:

- Definition of Asset Management
- Current Asset Management frameworks/elements
- Current Audit methodologies
- Asset Management Improvement and
- Business Process Engineering

### 2.2 Current Methods and Models

#### 2.2.1 Definition of Asset Management

Campbell [5] states that maintenance is one step in a nine-step asset management process. The process from Campbell [5] consists of the elements shown in Figure 1.

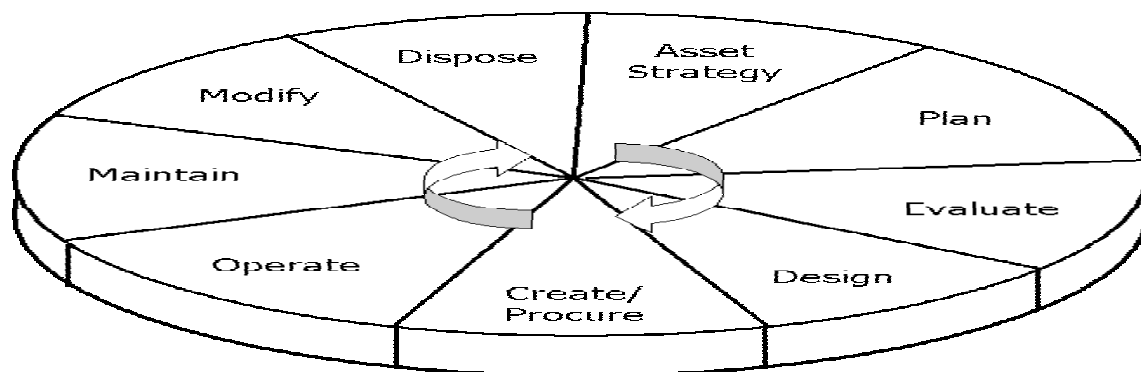


Figure 1 Asset Management Process [5]

Clarke [6] states that Physical Asset and Maintenance Management involves the management, co-ordination and execution of all the business activities and processes required through the physical asset's life-cycle, from identification of business need for a physical asset, through the acquisition, operation, maintenance and eventual disposal.

Advantage Technical Consulting (ATC) [7] describes Asset Management Performance Assessments as a tool to establish the status of asset management processes. In industrial business it is an essential first step in the challenge to match maintenance and asset management performance to business needs in an achievable and cost effective way. ATC [7] postulates that a holistic approach is the only way to guarantee sustainable improvements to asset management performance.

According to Woodhouse [1] AM is the set of processes, tools, performance measures and shared understanding that glues the individual improvements or activities, related to assets, together. Woodhouse [1] formulates a definition of Asset Management, when applied to physical assets, as "The set of disciplines, methods, procedures and tools to optimize the whole life business impact of costs, performance and risk exposures (associated with the availability, efficiency, quality, longevity and regulatory/safety/environmental compliance) of the company's physical assets."

ACM [8] states that maintenance must be defined and managed as a process. Processes need to be established in order to effectively manage maintenance activity and overall Asset Life Cycle Management.

ACM [8] postulates that there are essentially three stages in the life of an asset:

**Acquisition Phase:** At the beginning of the asset life cycle, business goals provide the inputs used during the design, procurement, installation and commissioning of the plant or equipment [assets]. The specifications developed during this stage relate to the physical characteristics and capabilities of the required assets.

**Operation and Maintenance Phase:** Business goals also define the requirements of how the assets will be operated. A known range of raw material will be processed into products and offered into the market place. Thus the business goals define the operating environment for the assets and the performance goals needed. The ability to deliver products to an eager market at lowest possible unit cost of production is the ultimate goal. Operational

performance is defined as a combination of production rate, quality and yield targets. Asset dependability is defined in terms of reliability and availability targets.

**Disposal Phase:** The end of the asset life cycle is reached when the asset is no longer capable of delivering the required operational performance, or cannot be cost effectively maintained to achieve the required levels of dependability. The options are either modification or disposal and replacement of the asset.

Peterson [9] states that Strategic Asset Management involves managing the capital investment towards a long-term program of increasing the return on assets.

Peterson [10] postulates that the term Asset Management implies some basic concepts:

- Business goals drive decisions regarding the use and care of equipment assets
- Asset strategy is determined by operational considerations
- Maintenance and reliability are means to a defined goal, not an end in themselves
- The intent is to optimize the application of all resources, not just maintenance

Peterson [10] defines AM as *a global management process through which we consistently make and execute the highest value decisions about the use and care of our assets.*

### 2.2.2 Current Asset Management Frameworks/Models

Campbell [5] explains that before an organization embarks on an improvement plan it should assess the strengths and weaknesses of the present system. The diagnostic must be a clear roadmap of the next steps to achieve their vision and should be comprehensive and cover strategic, procedural, technical, administrative and cultural issues. Campbell [5] suggests major areas included in the Asset Management framework as:

- Business characteristics
- Maintenance environment and strategy
- Organizational arrangement and human resource management
- Maintenance administration
- Planning, scheduling and work order management
- Preventative and predictive maintenance (tactics)

- Equipment records and histories
- Purchasing, storage, and parts inventory control
- Performance measurement and customer satisfaction
- Automation and information technology

Clark [6] postulates that an Asset Management Audit will critically examine your business's activities in the areas of:

- The business processes and activities employed through-out the physical asset life-cycle
- The business systems used to support these business activities and their degree of use
- The organizational arrangements and division of responsibilities for physical asset and maintenance management activities and processes
- The organizational culture as it relates to physical and maintenance management.

According to the ATC [7] framework, the complete business of Asset Management in industrial environments can be described as eight integrated processes as follows:

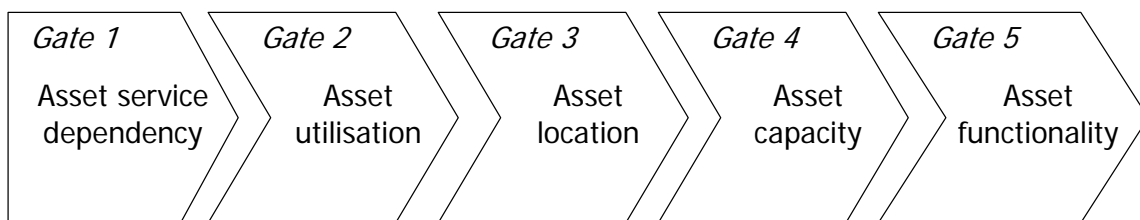
- Asset delivery and life cycle planning
- Equipment Reliability
- Planning and Scheduling
- Maintenance Management
- Skills assessment and development
- Contracted services
- Materials/Spares Management
- Computerized Maintenance Management System

A standard AM framework consists of 13 pillars or elements according to Taylor [11], which includes:

- Strategy Management

- Organization and Manpower
- Autonomous Maintenance
- Contractor Management
- Information Management
- Work Planning and Control
- Maintenance Tactics
- Continuous Improvement
- Performance Management
- Spares Management
- Tools and Workshops
- Financial Management
- Asset Acquisition

The NSW Government [2] developed a basic framework for the development of an Asset strategy. The framework considers each characteristic as a “gate” through which assets are analysed. The framework is shown in Figure 2.



**Figure 2: Total Asset Management framework [2]**

Asset Management is a set of integrated processes and according to Woodhouse [1] can be illustrated as in Figure 3 with the main processes as Resource control, Work control, Cost control and Change control. The basis of this process is the operating and maintenance strategies where the processes start and ends in the review of these strategies.

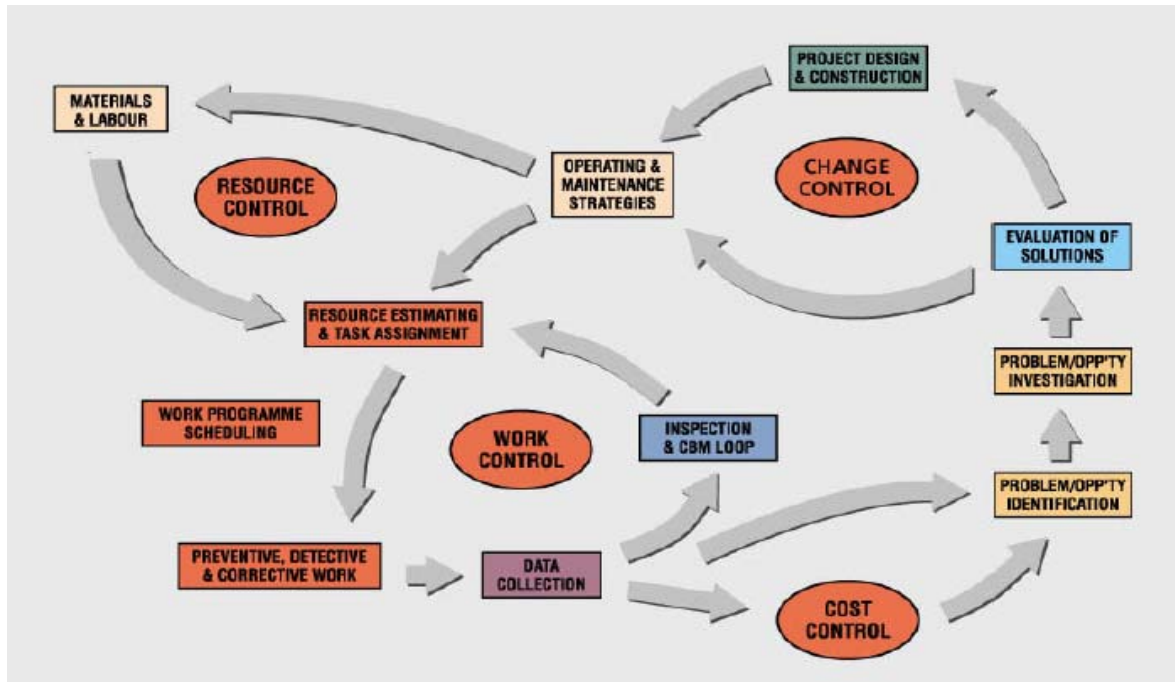


Figure 3: Asset Management Processes – The Big picture [1]

- According to ACM [8] an asset life cycle management system can be defined by the model/framework depicted in Figure 4.

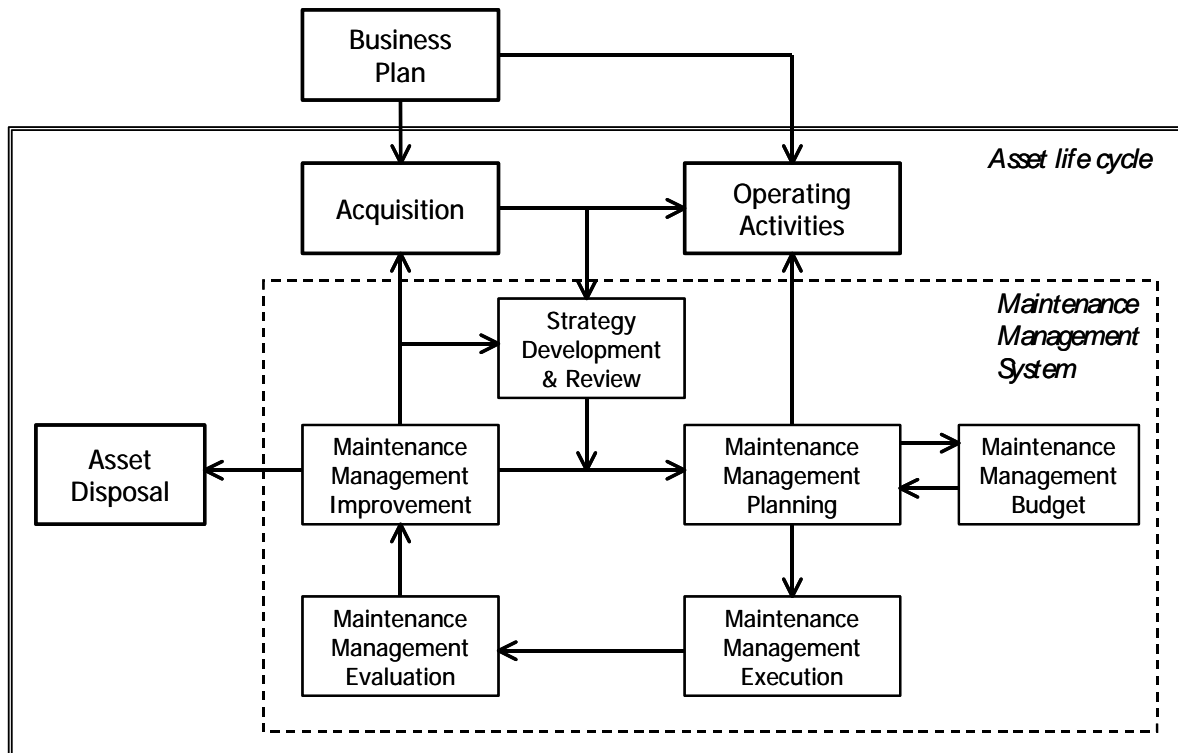


Figure 4: Asset Life Cycle Management Model [8]

According to Kaiser [3] the framework or key elements of the maintenance management audit consist of:

- A. Organization – Structure, Policies, Functions, etc
- B. Workload identification – Work request procedure, Preventive maintenance etc.
- C. Work planning – Prioritization, Classification, Backlog management etc.
- D. Work accomplishment- Planning and Scheduling, Transportation, Tools, etc
- E. Appraisal – Information systems, Performance Measures, History records, etc.

Visser [12] describes maintenance as a transformation process and applies the main functions of management to maintenance to create a maintenance management framework. According to Visser [12] the five functions/elements contains the following in the context of the maintenance system:

#### 1. Planning

- Strategy
- Objectives
- Maintenance Tasks

#### 2. Organizing

- Workload
- Structures
- Administration

#### 3. Staffing

- Recruiting
- Compensation
- Training

#### 4. Leading

- Influencing
- Motivation



- Communication

5. Control

- Cost

- Reliability

- Resources

Wordehoff [13] postulates that identifying the current stage of excellence is the best place to begin. He states that maintenance maturity can be described along the dimensions/elements of:

1. Organization

2. Work practices and

3. MRO materials management

Ferguson [14] points out that a holistic and evergreen approach to asset management processes provides the capability to change the nature of work and drive a reliability-centred culture. In his model, Ferguson [14] presents the integration of “best” processes to create a world-class approach to AM. Ferguson [14] illustrates in his diagram that AM consist of a set of processes and sub processes with a high level flow between each. The elements in his framework for asset management include the following high-level processes:

- Criticality ranking process
- Front-end failure analysis (e.g. FMEA)
- Equipment reliability strategy development (e.g. Template or Specific)
- Equipment reliability strategy implementation (e.g. Loading of Tasks)
- Work Management (e.g. Planning, Scheduling and Execution)
- Reliability analysis (e.g. Root cause failure analysis) and
- External processes (e.g. Capital projects)

Referring to maintenance, Tomlinsong [15] describes the purpose of the evaluation as a “checklist” describing what maintenance should be doing and that the results should describe how they did providing a basis for developing an improvement plan. Tomlinsong [15] set the framework for such an evaluation or audit to include:

- The Organization – Labour control and productivity, Motivation and Training.
- The Program – Preventative maintenance, Planning, Scheduling, Technology.
- The Environmental – Policies, Procedures, Housekeeping, Material control.

According to Peterson [10] implementing AM is a process and contains the following elements:

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

According to Vosloo [16], an audit framework addresses the following:

- outline of process flow diagram of production process,

- site objective and maintenance objective including production policy, critical units, scheduling characteristics and existing maintenance strategies,
- maintenance workload,
- maintenance resource structure,
- maintenance work planning and control,
- administration structure,
- maintenance cost control and
- documentation (CMMS and Manual)

MacArthur [17] postulates that the following is the core of Enterprise Asset Management:

- **EAM strategy** defines how we expect to produce the highest capacity at the lowest cost. Normally this includes measurement and tracking of continuous improvement based Key Performance Indicators integrated with resource and planning optimization strategies such as Reliability Centered Maintenance and/or Total Productive Maintenance. EAM strategy is exceptionally important in the overall concept of EAM since it sets the direction and tone of where we are going with all the other elements.
- **MRO processes** is the second structural component of EAM which describes producing maximized efficiency and results within the myriad of major and minor processes. Some of these processes include inventory management, work planning and estimating, MRO purchasing, calibration management, capital projects, scheduling as well as other major and minor processes. In order to get the maintenance work accomplished, support EAM strategy objectives and capitalize upon installed EAM technologies, these processes must be engineered to the highest degrees of efficiency, and common sense.
- **EAM technologies** constitute a major enabler within EAM. They span the spectrum from high-end, enterprise-wide Computerized Maintenance Management Systems (ironically, otherwise called EAM systems), Calibration Management Software, Pressure Vessel and Valve Tracking applications, Predictive Maintenance software, Hand-held applications and so many more. The chief function of these applications is to use basic engineering data in order to provide an automated tool set to support MRO process operations, while simultaneously producing empirical data suitable for analysis and KPI tracking.

- **Engineering Data Content** represents the element-level electronic information that defines an organizations asset base, inventory stock, operations, resources and maintenance procedures. Engineering data serves as the basic building block of the overlaying technology tools, which in turn are used to support MRO processes. Fundamental EAM strategy execution is impossible without the data, systems or processes.
- **People.** The final element of EAM is people, people, and people. People are the obvious key ingredient in all aspects of the business function. People form and track the EAM strategy. People perform the MRO operations. People install, configure and maintain the EAM technologies. People create and maintain the engineering data. Finally, people turn the wrenches that maintain the assets that are operated by people who generate the products or services for which the organization exists. Obviously people are the binding element, the glue that holds the entire structural integrity of EAM together. They need to be trained, organized and deployed throughout the EAM function.

### 2.2.3 Current Audit Methodologies

ATC [7] methodology or process for conducting an Asset Management Audit or Assessment includes the following steps:

Step 1: A consultant facilitates a group discussion addressing questions structured in line with the eight integrated processes mentioned earlier. Each main process is further broken down into constituent sub-processes and uses a mixture of “hard” performance measures and the presence/absence of basic processes. The group will be made up of individuals who are knowledgeable about the way the processes under examination actually operate on the plant. These group discussions are supplemented by site tours and analysis of relevant information.

Step 2: The responses to the questions are input directly to the database and the results are output in the form of “web” charts. Charts are produced for each of the eight processes and combined into a single aggregated results chart.

Step 3: The results are presented and recommendations to the clients communicated. The session is run as a workshop. Discussion is encouraged on prioritising the change program and also on identifying the potential barriers to the realisation of the benefits.

NSW Government [2] has set some audit/assessment criteria for an agency to determine their uptake of Total Asset Management. Three categories of agency development have been identified:

- Level 3 :  
Input oriented project focus – attention is paid to individual projects.
- Level 2 :  
Output oriented asset focus – attention is paid to asset performance and output.
- Level 1 :  
Outcomes oriented service focus – attention is paid to resources that are aligned to achieve service outcomes

Six major criteria have been established in alignment with the Total Asset Management approach. An Asset strategy is considered to have complied with criteria if it includes that aspect in sufficient depth to make the strategy and its outcome effective. The NSW Government [2] major six criteria used to assess or audit the AM strategies at an agency include:

- Corporate goals and service measures defined
- Asset strategies developed
- Asset output and performance targets defined
- Capital investment, maintenance and disposal plans developed
- Asset performance data collected and reported
- Opportunities to improve asset performance systematically identified.

Kaiser [3] devised a 7 phase auditing methodology; the basic phases of this audit methodology can be shortly described as follows:

Phase I: Establish Priorities and Schedule

Prepare a draft review schedule and nominate activities to be reviewed; suggest priorities and review time frames.

#### Phase II: Define and Organize the Audit

Review functional areas and procedures pertinent to the functional areas; identify potential audit team members and establish a work plan for the audit.

#### Phase III: Form the Audit Team

Select members of the audit team and arrange with department heads for members' participation. Prepare detailed task plans using functional area outline and orientation materials previously assembled by staff and assign specific tasks to team members.

#### Phase IV: Perform the Audit

Collect data, review policies and procedures, conduct interviews with unit staff, utilize opinion poll questionnaires, review budget documents.

#### Phase V: Prepare the Report

Formulate recommendations of alternative approaches to operations and organizations to assist management in solving identified problems. Review, approve, and distribute the final report.

#### Phase VI: Management Action

Submit a plan of action responding to audit team recommendations. Obtain agreement and support from department manager(s) and supervisor on action plan items.

#### Phase VIII: Final Follow-up of Results

Monitor the implementation process and submit a progress report on implementation to the steering committee.

Idhammer [18] states that it is important to do maintenance efficiency assessments on a regular basis, but advises to keep it simple. Idhammer [18] recommends to:

- Establish your own key factors
- Define areas in which you can improve
- Setup and commit to realistic goals

- Document an improvement plan
- Implement the improvement plan and use key factors to measure progress, motivate, educate and guide future action.

Idhammer [18] postulates that when implementing improvements, use the goals expressed as key factors to motivate and encourage people.

According to Hoberg and Rudnick [19] the steps for an assessment/audit are as follows:

1. Managers determine and communicate the need for the assessment.
2. Managers plan the scope and identify the members of the assessment team. They also determine the assessment process based on desired outcomes and investment limits.
3. Consultants train the assessment team in the relevant criteria/process. The team clarifies the assessment scope and categories.
4. The team prepares for the assessment by researching or surveying the organization for supporting data or information, prepare documentation or presentation material.
5. Conduct the assessment with the consultant as a facilitator.
6. Compile and distribute the findings.
7. The organization determines and prioritizes improvement opportunities.
8. Managers or process management teams initiate and manage improvement opportunities.

Tomlison [15] describe a ten step evaluation strategy (or methodology) which includes the following:

- Step 1 – Develop a policy on evaluations/audits.
- Step 2 – Provide advance notification.
- Step 3 – Educate personnel.
- Step 4 – Schedule the evaluation.
- Step 5 – Publicize its content.
- Step 6 – Use the most appropriate evaluation technique.
- Step 7 – Announce results.
- Step 8 – Take immediate action on the results.

Step 9 – Announce specific gains.

Step 10 – Specify the dates of the next evaluation.

### 2.2.4 Asset Management Improvement

Campbell [5] states that as part of the audit, each element is scored and plotted either on a histogram or on a Bell-Mason type spider diagram. A simple grid, measuring the broad areas against the current status gives a qualitative score from “Innocence” to “Excellence” as show in Figure 5.

	Strategy	Planning & Scheduling	Performance Measures
<b>Excellence</b>	Set corporate maintenance strategy/asset strategy.	Long-term and project planning and Engineering.	Equipment effectiveness; benchmarking; full cost database.
<b>Competence</b>	Long-term improvement plan.	Good job planning, scheduling, engineering support.	MTBF/MTTR available; separate maintenance costs.
<b>Understanding</b>	Annual improvement plan.	Planning group established; ad hoc engineering.	Downtime by cause; maintenance cost available.
<b>Awareness</b>	PM Improvement plan.	Troubleshooting support; inspection scheduling.	Some downtime records, maintenance cost not segregated.
<b>Innocence</b>	Mostly reactive to breakdowns.	No planning; little scheduling; no engineering.	No systematic approach; maintenance costs not available.

**Figure 5: Maintenance “Innocence-to-Excellence” evaluation [5]**

According to Campbell [5] once the organization understand where he stands through the assessment, the following steps should be applied:

Step 1 is to develop vision and a mission.

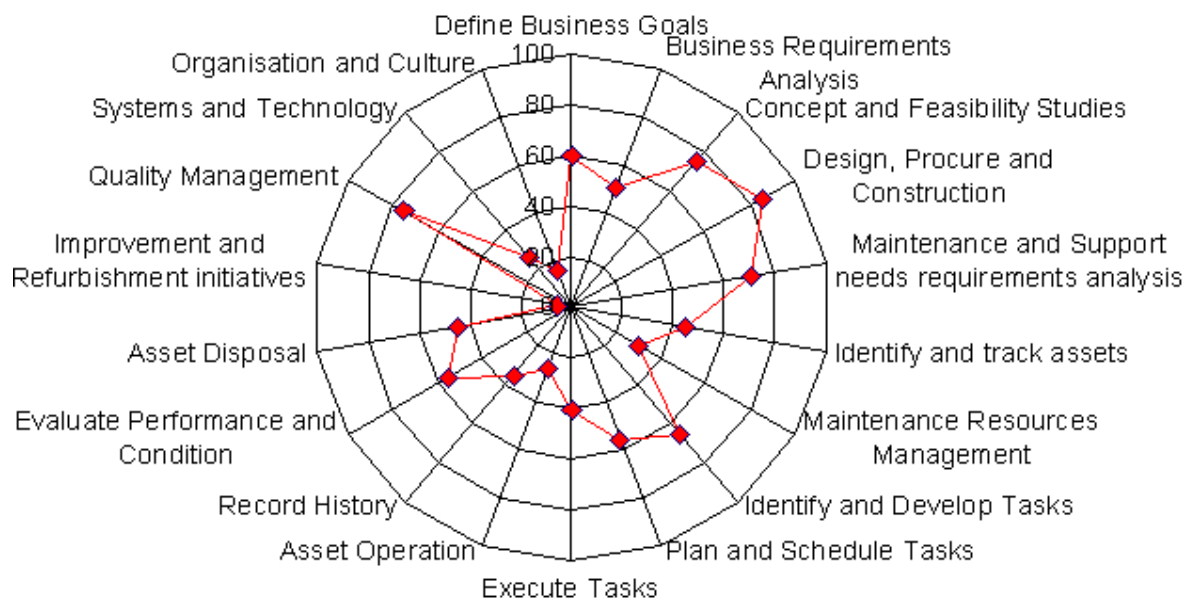
Step 2 set objectives to bridge the gap between reality and the vision.



Step 3 includes the development of actions to reach the objectives, on a timetable, with a dedicated champion, committed resources and a structured implementation plan. Progress review meetings should be conducted to share successes and manage frustrations.

According to Clark [6] the outcomes of the audit will be:

- A ranking of your business’s Physical Asset and Maintenance Management performance and practices. Figure 6 displays typical results on a Bell-Mason spider diagram.
- A gap analysis of your business against “best practice” Physical Asset and Maintenance Management
- Recommendations for performance improvement to bridge the identified performance gaps.



**Figure 6: Audit results on Bell-Mason type spider diagram [6]**

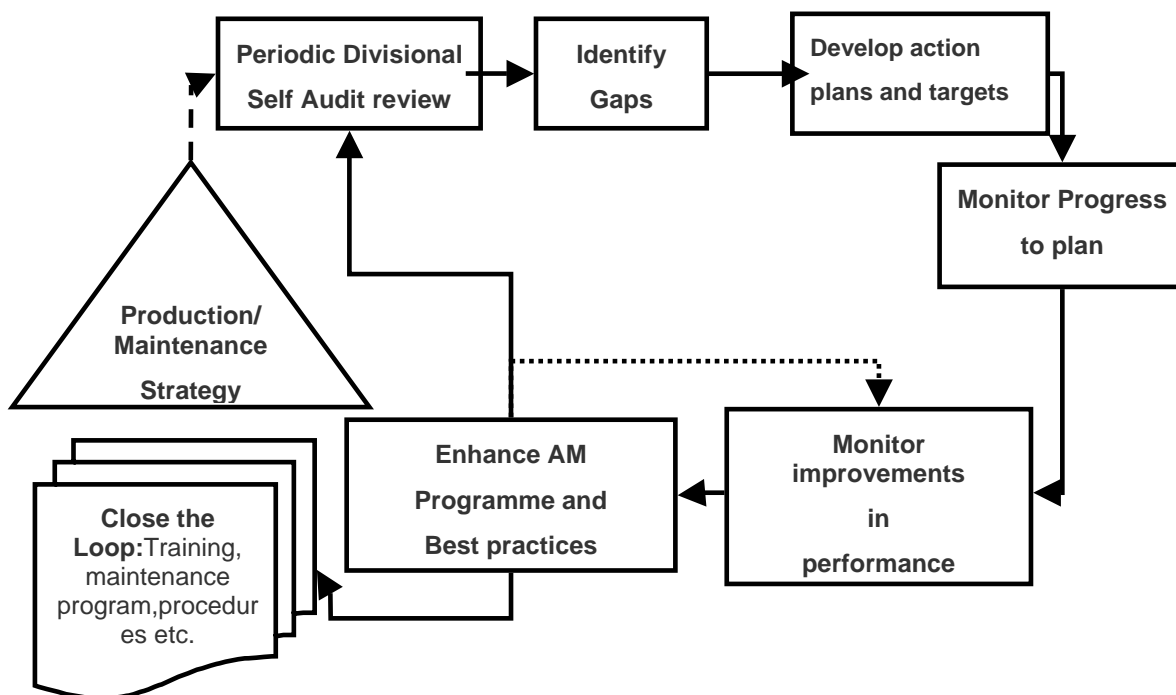
Clarke [6] postulates that “best practice” Physical Asset and Maintenance Management is moving from being a competitive edge to a business necessity.

According to ATC [7] the general benefits of an Asset Management Audit or assessment includes:

- Identifying where and how improvements can be made
- Creates a roadmap for improvements

- Focuses on developing best practice asset management processes
- Drives continuous improvement and focused business planning
- Highlights financial business opportunities
- Communicates the need for change and improvement
- Identifies internal strengths to support the change process.

Taylor [11] postulates that the Asset Management Improvement Plan (AMiP) is a best practice improvement methodology that provides an AM framework and improvement guidelines to grow the enterprise to sustainably improve asset performance at optimum life cycle cost. The AMiP growth model, as depicted in Figure 7, shows that the Corporate and Operational Strategy forms the basis of an AM strategy where after a framework (standard or custom) will be established.



**Figure 7 AMiP Growth Model [11]**

The AM maturity is mapped normally through an audit and based on the findings an improvement plan is developed and implemented. Important to note is that Change Management should be exercised throughout the improvement program and progress measured on a regular basis.

Wordehoff [13] refers to a “stages of excellence” framework that will help companies to achieve competitive advantage. According to Wordehoff [13] this approach recognizes that functions such as maintenance develop through stages of maturity from entrepreneurial fire-fighters (Stage 1) to world class competitors (Stage IV). Wordehoff [13] suggests a quick self-assessment according to the framework and describes the different stages according to Figure 8.

<b>Stages of Excellence in Maintenance Management</b>				
<b>Maintenance Dimension</b>	<b>Stage I</b>	<b>Stage II</b>	<b>Stage III</b>	<b>Stage IV</b>
Organization	Centralized 2 hourly per support staff*	Some area focus 8 to 10 hourly per supervisor	Strategic training Multiskill flexibility Decentralized	Empowered teams 4 hourly per support staff Production operators execute PM
Work practices	Reactive Direct work† <25%	Plan shutdowns Daily schedule PM focus begins	60% planned work Weekly schedule Predictive maintenance	Reliability engineering Direct work >50% Craft-assisted planning
MRO materials management	Absence of management practices Uncontrolled access to parts	Computerized Turns <1.0 Few performance measures	Vendor alliances Streamlined purchasing	On-line requisitions Materials QA/PM Turns >1.5
Descriptor	Fire-fighter	Controller	Innovator	Best of the best
* Support staff includes management, supervision, clerical, maintenance engineers, storeroom personnel, and others † Direct work is the percentage of field time spent in hands-on activities				

Figure 8: Stages of Excellence in Maintenance Management [13]

Hoberg and Rudnick [19] postulates that collectively, assessments provide a comprehensive means to both control and improve systems, processes, products and services. Assessments play a key role in the ability to satisfy customers, shareholders and employees.

Peterson [9] describes an empirical model of five stages of mastery that create a foundation of improved performance with growth potential. Peterson [9] postulates that by describing the role of maintenance, operations, engineering, accounting and management in the improvement cycle, the organization can guide creation of a strategic plan for improvement, tied with bottom-line performance expectations.

Peterson [9] further explains that the implementation of such a strategic plan requires the proper structure, measures, information and commitment. The major steps included in the maturity continuum to reach AM Excellence according to Peterson [9] include:

Stage 1 – Gain control of the work (Daily maintenance)

Stage 2 – Gain control of the equipment condition (Proactive maintenance)

Stage 3 – Create the environment to maximize the contribution from your people (Organizational Excellence)

Stage 4 – Systematically eliminate sources of potential system failure (Engineered Reliability)

Stage 5 – Assure alignment of financial operations, corporate leadership, sales and marketing, and customers (Operational Excellence)

Vosloo [16] states that there are many ways available to do an audit and that it is important for the company to understand exactly what is being measured and what the results of such an audit means. Vosloo [16] postulates that an audit is not a once off event, but should be repeated at regular intervals to ensure continuous improvement.

### **2.2.5 Business Process Engineering**

Malhotra [20] notes a five-step approach to business process re/design:

1. Develop the Business vision and process objectives.
2. Identify the processes to be re/designed
3. Understand and measure the existing processes
4. Identify IT/Systems levers
5. Design and build a prototype of the process

Malhotra [20] also notes that processes may be defined based on three dimensions:

- Entities – Processes take place between organizational entities. They could be Inter-organizational, Inter-functional or Interpersonal.
- Objects – Processes result in manipulation of objects. These objects could be Physical or Informational.
- Activities – Processes could involve two types of activities: Managerial (e.g. develop a budget) and Operational (e.g. fill a customer order)

Hoberg and Rudnick [19] state that an audit (or assessment) provides useful information on areas where processes were not compliant. As a result identified processes that needed to be documented/modified and areas where processes were not being executed as defined is highlighted. The role of the auditors, according to Hoberg and Rudnick [19], was first to review the documented process (e.g. Requirements development, testing, process management) to ensure that the process was compliant with the relevant standard and consistent with the policies defined. Secondly, auditors looked at the execution of the process to ensure that it was executed as described within the documentation. It was also important to ensure that the executors were adequately trained to execute the processes they used.

Tritter [21] postulates that the single most important – and sometimes most difficult – step in improving business performance is to view the entire organization as a set of processes. According to Tritter [21] *Controlled Self Assessments* (CSA) can be used to analyze business processes and improve on them. These CSA sessions follows a pattern of asking four questions for every step in a process:

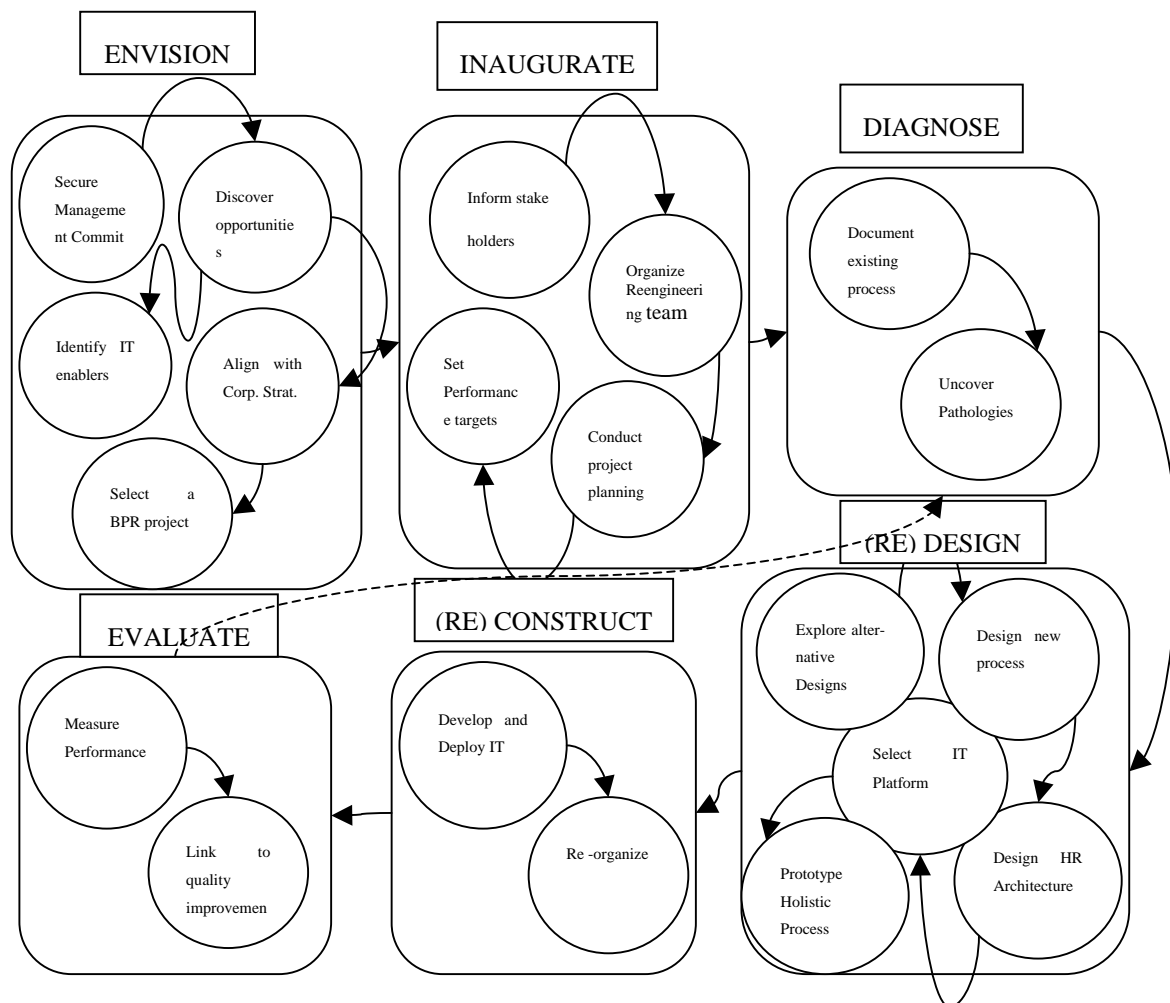
1. Introduction – How does this work?
2. Positive issues – What is successful here? Deepens participant knowledge and recall of the subject matter.
3. Negative issues – What is not working well? The key question that you were leading up to: Where are the problems?
4. Recommendations – How to fix the problems? A short discussion of immediate thoughts, no deeper. Then move to the next process or process step.

According to Grover [22] a business process is a group of logically related tasks that use the resources of an organization to provide defined results in support of the organization's objectives. Grover [22] states that if properly constructed, a Business Process Engineering (BPE) methodology is designed to steer the engineering of business processes toward success. As a roadmap the methodology should act as a guide rather than a rigid set of rules that must be followed in an inflexible order. In this way BPR methodology should guide analytical thinking without a built-in bias toward one "right" answer. This introduces Process Reengineering Life Cycle (PRLC). Grover [22] based this on analysis and synthesis of many

of the leading BPR methodologies and techniques used in practice, the PRLC methodology represents the stages and activities of a typical business process reengineering project.

According to Grover [22] the sequence of steps may be divided into three broad phases: conceptualization of a project, creation of a new process, and integration of that process into the organization. Grover [22] uses the metaphor of life cycle for reengineering therefore these three phases may further be divided into the six stages of the Process Reengineering Life Cycle (PRLC) as represented in Figure 9.

Grover [22] also states that as a prerequisite to identifying candidate processes for reengineering, the top management task force should conduct a high-level evaluation (or audit) of existing business conditions and performance in the context of corporate strategy. A clear assessment of corporate goals, objectives and Key performance indicators should be outlined.



**Figure 9: Process Reengineering Life Cycle [22]**

According to Grover [22] documenting the existing processes, or “process capture” as it is often referred, involves the capture of activities, resources, controls, business rules and information flows. This includes the representation of relationships between activities, information and other relevant process characteristics. This task must develop high-level diagrams of the selected process and also decompose this into sub-processes. Several levels of decomposition may be necessary. The following guidelines should be used as proposed by Grover [22]:

- Depict the process from its starting node to its end node, which may include several functions, departments, internal and external customers and external linkages.
- Identify components of the process such as information systems, human, controls, physical and other process resources.
- Document the performance of the existing process in terms of customer satisfaction, inventory turnover, cycle time, waiting queues, defect rates, activity times, transfer rates, priority rules, and other relevant measures.
- Decompose the large process into a set of sub-processes and assign BPR team members to the appropriate sub-processes based on their expertise.

A proposition from Grover [22] is that after implementation, an ongoing task should be the monitoring and evaluation of process performance. This may include the dynamic monitoring of qualitative and quantitative performance measures as set in the INAUGURATE stage. Continued evaluation of the (re)designed process is especially important in the early stages of deployment. An efficient feedback loop must exist between the EVALUATION and the DIAGNOSE stage as indicated in Figure 9. Such a loop provides an audit of the performance of the (re)designed process and identifies other needed modifications to adapt to change.

### **2.3. Need for Improved Method and Model**

Many different auditing methodologies and frameworks exist currently as researched and described above. Different definitions for Asset Management have been developed according

to its meaning for the relevant entity or organization. A need exist in the AM field for a consolidated auditing methodology or process. This will include:

- The integration of business process engineering and AM as two interdependent philosophies as it is important to highlight that many of the improvements will depend on the successful re/engineering of business processes in Asset Management.
- The consolidated framework on which the audit is conducted should include the necessary elements to ensure that no possible opportunity for improvement is missed and that the scope of AM is clear. As shown in the research many different frameworks are in existence and the different elements in each framework need to be grouped into the phases of an assets life cycle as a high level framework.
- The improvement strategy/activities after the audit to advance the organization to excellence in AM. This is the most important stage of any audit where the gaps or opportunities identified must be addressed in a concerted effort and in a structured way. The research has again shown that there are different processes in existence, but that none mentioned the importance of Business Process Engineering as an important tool in the improvement stage.



## **CHAPTER 3: THEORETICAL FRAMEWORK/CONCEPTUAL MODEL OR METHOD**

### **3.0 Introduction**

As this is a theory-building study, and by applying deductive reasoning, new methods and models have been developed. Tomlinsong [15] has the opinion that desired performance improvements are often not realized because the evaluation (or audit), the first step of improvement, is not done adequately. Tomlinsong [15] states that without evaluations (or audits) the specific improvements in performance that could help assure profitability are often never identified. In this chapter Asset Management will be defined, the new framework developed for Asset Management will be illustrated and discussed. The audit methodology developed will be presented in detail as well as the strategy to develop the “roadmap” to Asset Management Excellence.

### **3.1 Asset Management Defined**

A number of different definitions for Asset Management have been mentioned in Chapter 2. Asset Management, referring to physical equipment and structures, can be best described on a high level as the management of these physical assets through its entire life cycle. This life cycle include the following phases:

- Asset Acquisition,
- Asset Operation,
- Asset Maintenance and
- Asset Disposal.

In most instances it is also expected that when an investment is made on acquiring an asset, that there would be a return on such an investment. The ideal is that revenue generated by an asset should be maximised and the life cycle cost of the asset optimized for the highest possible profitability. In a services environment the focus might be more to the optimization of the costs associated with an asset, than on the revenue generation (e.g. a government

school). The performance of the asset would still be a focus point to ensure that expectations are met or exceeded for the purpose that the asset was acquired.

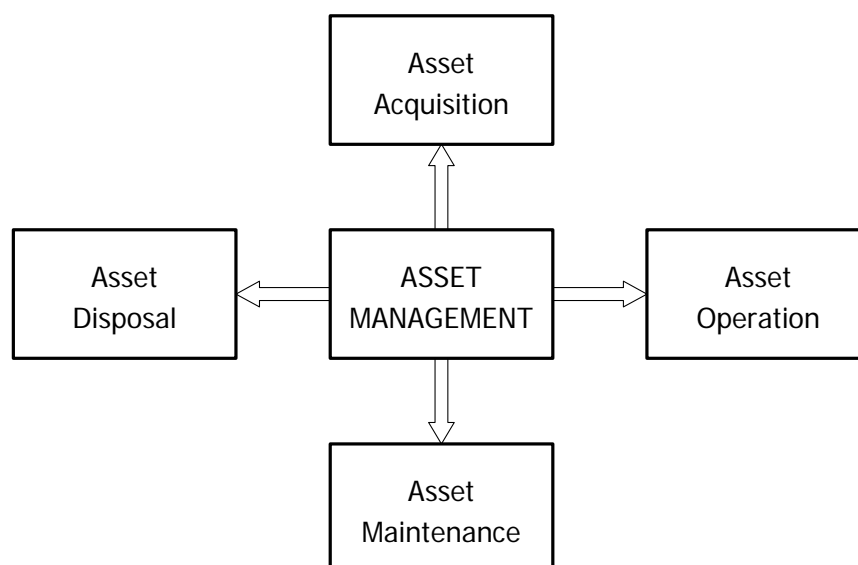
Therefore, Asset Management can be defined as:

*“The management of physical assets through its acquisition, operation, maintenance and disposal life cycle phases in order to optimize life cycle costs and maximise contribution to profitability or success of an organization”*

### 3.2 Asset Management Framework

According to the definition of AM, the new high-level framework for AM will include the four phases of the asset’s life cycle. This gives a holistic scope for the concept of AM and clearly shows that maintenance management is only one of the elements in AM. The research performed has shown many different frameworks and elements in the discipline of Asset Management. These different frameworks and elements have been reconciled and integrated to form the new framework with its sub elements for Asset Management. Figure 10 illustrates the new high level framework for AM.

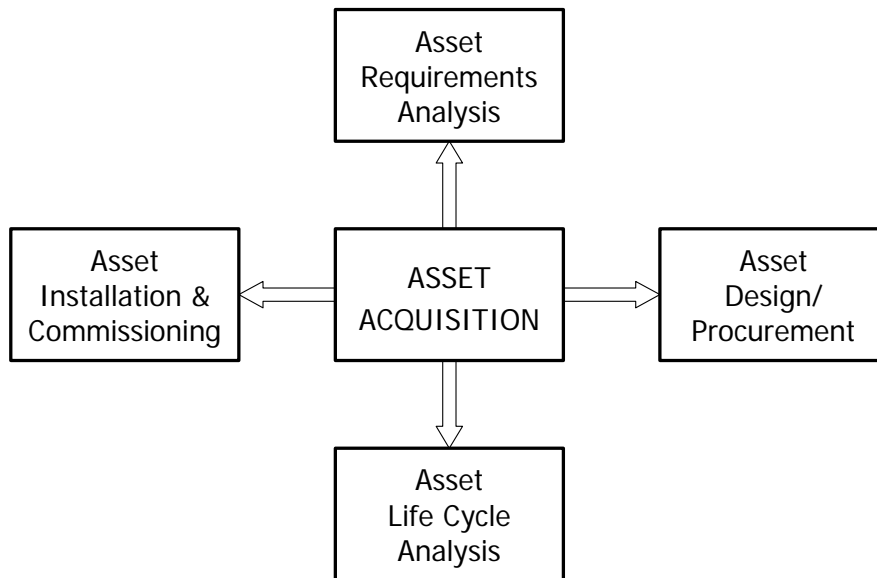
Each of these main four phases can be further developed into its own sub set of elements that constitute what that specific life cycle phase entails. The basic division for each of these four phases with their respective elements is illustrated in the following diagrams.



**Figure 10 - High-level framework/model for Asset Management.**

### 3.2.1 Asset Acquisition

In Figure 11 the Asset Acquisition phase of a physical asset's life is divided into the elements of Requirements Analysis, Design/Procurement, Life cycle analysis, Installation and Commissioning.



**Figure 11: Asset Acquisition framework/model.**

#### 3.2.1.1 Asset Requirements Analysis

When the corporate strategy is set, certain requirements and targets will be highlighted in it. Physical assets in the form of equipment and structures will be needed to realize the goals that have been set out. The requirements of the assets will be determined based on the current assets or, if necessary, the acquisition of additional assets. These requirements can be set in terms of productivity-, economic- or integrity factors. It is important to identify and include future expectations in terms of growth or other issues that can influence the requirements from the assets.

#### 3.2.1.2 Asset Design/Procurement

The design and/or procurement of assets can include the detailed engineering of equipment and structures, the fabrication or manufacturing of these assets (normally from outside suppliers) or might only be the placement of an order for an off-the-shelf asset. The ergonomics and maintainability of the assets must be given attention in this element.

### **3.2.1.3 Asset Life Cycle Analysis**

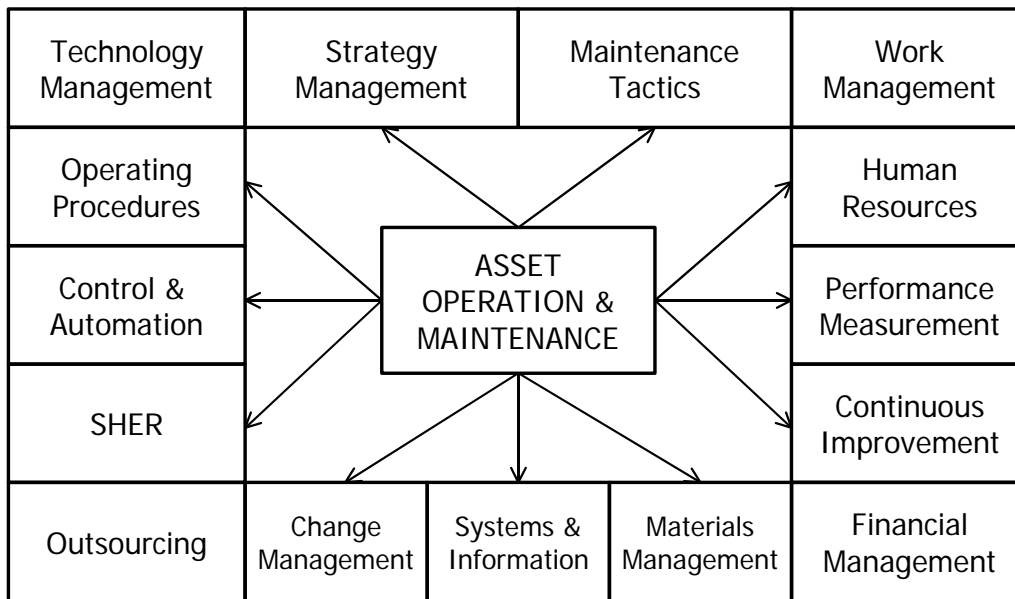
This is often a neglected element of asset acquisition. This will typically include RAM (Reliability, Availability and Maintainability) analysis to determine what the requirements and/or deliverables of the asset are in terms of the expected reliability, availability and maintainability targets. Life Cycle Cost analysis or sometimes referred to as, “Total Cost of Ownership”, is another factor to be determined as part of this element. It is important to perform this exercise before an asset is acquired so that the optimum replacement, overhaul or disposal time may be determined beforehand. It will also assist in deriving a budget to operate and maintain the asset.

### **3.2.1.4 Asset Installation and Commissioning**

This element of asset acquisition is a very important phase in the life of the asset. Care must be taken during the installation to ensure that the construction or other activity, by which the asset is installed, is carried out according to the correct procedure. The life of the asset can be drastically influenced if the installation is not done correctly and to the required standard. During commissioning of the asset it is imperative that the correct operating and maintenance plans are loaded and that the personnel, responsible for executing the plans, is properly educated in doing so.

### **3.2.2 Asset Operation and Maintenance**

For the purpose of eliminating duplication Asset Operation and Asset Maintenance is combined as illustrated in Figure 12. The Asset Operation and Maintenance phase consist of the elements: Strategy Management, Maintenance Tactics, Work Management, Human Resources, Performance Measurement, Continuous Improvement, Financial Management, Materials Management, Systems and Information, Modification/Change Management, Outsourcing, SHER, Operating Instructions/Procedures, Control / Automation and Technology Management.



**Figure 12: Asset Operation & Maintenance framework/model**

### 3.2.2.1 Strategy Management

It is the structured process for managing the asset management strategy. This includes the systems and processes for the development, communication, implementation, measurement and review of the asset management strategy. The process to develop and implement an asset management strategy for an organization must at least address the following in support of the corporate strategy:

- Vision/Mission
- Values/Principles
- Key Performance/Focus Areas
- Objectives and Key Performance Indicators
- Program for Asset Management Improvement
- Asset Management Improvement Program Review and Steering

### 3.2.2.2 Maintenance Tactics

This is the structured process to analyze and understand failure modes of assets and the application of the most appropriate maintenance tactics to prevent these failures. This includes

the systems and processes to decide on the available tactics (breakdown, scheduled, condition based, re-design) as well as the supporting tools and techniques (e.g. RCM) to achieve and sustain the inherent reliability of an organization's assets. The criticality of an asset should permit the application of certain maintenance tactics. It involves the application of the optimum maintenance mix on the assets to ensure the lowest total cost of preventative and reactive maintenance. Improvement on the application of condition monitoring techniques to detect imminent failures before they occur must be a focus point. The application of proactive maintenance principles e.g. Lubrication and fuel quality and cleanliness, should be driven.

### **3.2.2.3 Work Management**

This is the structured process to plan and control all maintenance tasks. This includes the systems and processes for the planning and scheduling of maintenance activities (including shutdowns), the allocation of resources, reporting and feedback as well as the quality control of work. To ensure that the contribution made by maintenance to the achievement of the operational, and hence, company business objectives is fully optimized proper work management principles must be employed. 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 for the plant. Planning for the utilization of maintenance resources to ensure a cost effective maintenance and optimum utilization of the resources should be of prime importance. The infrastructure required in the form of adequate workshop facilities and tools, to perform work, are included in this element. Adherence to the routine maintenance programme and statutory requirements to ensure plant integrity and safety as well as proper logistics planning to eliminate waste and ensure work quality, should form part of the deliverables of this function within Asset Management.

### **3.2.2.4 Human Resources**

This element addresses the people issues. It is the structuring of the enterprise with competent staff to perform the required functions. This includes the organisational structure and the policies and procedures for job profiling, performance management, skills and competency development as well as rewards and incentives. Leadership and culture of the organization may be included.

### **3.2.2.5 Performance Measurement**

Performance Measurement is the structured process for measuring the effectiveness of the asset management function. This includes the systems and processes for the identification of measurements, the setting of targets, the measurement and displaying, as well as the analysis and interpretation of measured results. Some of the objectives of Performance Measurement are to develop and drive the correct performance management practices within asset management. That should enable reliable and accurate information becoming available to assist in the effective management and decision making process of the operation and maintenance of physical assets. Problem areas can be identified and benchmarking can be done to develop and sustain best practices. “What you measure is what you get” - Identifying and tracking the right key performance indicators can assist in optimizing the performance of physical assets. Certain systems, for example, the Balanced Scorecard can support the tracking and improvement of identified measures. The identification of the *right* measures is key to the results that can be expected. Ensure that the measures or metrics that have been identified supports the strategy. A good rule of thumb is to assign measures according to the framework elements. This indicates the success and performance in each of them. Measuring them all might be cumbersome and it is advisable to start with a number of elements that is being focussed on and are deemed more critical at that stage.

### **3.2.2.6 Continuous Improvement**

It is the structured approach to continually improve asset management performance. This includes the systems, policies, procedures and tools (e.g. Six Sigma) for the prioritising and analyzes of performance gaps, development and execution of improvement plans as well as the formalising and establishment of best practices. Improvement action plans are put in place to address the “gaps” from current state to desired/future state. It includes identification of problem areas and opportunities, ranked according to impact or criticality, applying proper root cause analysis and problem solving methods, thereby ensuring the elimination of re-occurrence. A culture of faultfinding and elimination need to be established in the workforce. It is also important to track and review the effectiveness of the solved problems and have multi-disciplinary team involvement in the continuous improvement effort.

### **3.2.2.7 Financial Management**

It is the structured process to manage all the financial aspects of asset management. This includes the systems and processes for budgeting, expenditure control, reporting and financial decision-making. Zero based or Activity based budgeting should be employed to optimize the allocation of budgets for the operation and maintenance of assets. Life Cycle Costing and Total Cost of Ownership is some key issues that need to be supported and driven by the financial system and process.

### **3.2.2.8 Materials Management**

This is the structured process to manage spares and materials. This includes the systems and processes for the provisioning, stock holding, issuing of materials and spares as well as optimization of the holding facilities. Proper materials management processes and systems should ensure the availability of the correct spares and materials, of an acceptable quality, to the operations and maintenance for the timely execution of activities. Delays due to unavailability of materials and spares to production must be prevented. A proper refurbishable equipment management process must support the reliable operation of the physical assets. This should ensure that when assets are repaired or overhauled a set standard and procedure is followed and a rigid quality control process takes place. The tracking of warranties on repairs and overhauls must be part of the refurbishable equipment management process. Maintenance and Operation activities should dictate what materials and spares will be kept available and in what quantities according to the maintenance and operations plans. Another important factor to include is the negotiation of alliances or partnerships with suppliers; this can reduce the operation and maintenance cost associated with materials and spares.

### **3.2.2.9 Systems & Information**

Systems are installed to support and enable the execution of business processes within an organization. Data is generated continuously from the assets and activities performed on and around assets. This can include data concerning operating parameters, resource usage, maintenance tasks performed and materials or capital consumed by an asset. This data can be transformed into usable information assisting in the decision making of the owners.



Information that can generally be acquired includes throughput, process parameters, power consumption, breakdown history, labour allocation etc. Statistical analysis is one of the tools that can determine the optimum operating parameters for an asset in a plant environment. Data has to be recorded in a proper format so that it allows easy extraction and manipulation to provide the required information. It is also important to ensure integration between the different disciplines and departments to consolidate the information e.g. financial, materials and maintenance management. Systems should be user friendly and provide the required information, may it be drawings, procedures or performance graphs (associated with the relevant asset) with relative ease.

#### **3.2.2.10 Modification/Change Management**

“The only thing that is constant is change” - In the organization, changes to processes and equipment take place regularly. These changes need to be managed properly. A system and process has to be put in place that will administrate and control the changes or modifications to assets. For example, a modification to an asset can require drawings to be updated, maintenance plans might need to be revised, and operating instructions can require adaptation as well as the material requirements from the stores can change. All these issues have to be taken into consideration when modifications or changes are made to existing assets or plants.

#### **3.2.2.11 Outsourcing**

This element addresses the structured management of all outsourced work and includes the systems and processes for the selection, contracting, and performance management of contracts. Outsourcing of maintenance has been seen to grow in the past few years. More and more organizations want to focus on their core business, be it mineral extraction, consumer goods manufacturing or government services. There can be good reasons to outsource but care must be taken when the scope is determined and the contract set up. The outsourcing of maintenance must deliver value by reducing costs and increasing the performance of assets. If both of these are not achieved by outsourcing then the viability of outsourcing should be revised.

#### **3.2.2.12 Safety, Health, Environment and Risk (SHER)**

Associated with assets certain Safety, Health, Environmental and Risk issues has to be identified and managed. Law governs the operation and maintenance of certain assets and the requirements set out should be adhered to at all times. These requirements must be included in the operation and maintenance plans for the assets to ensure conformance and prevent possible fines, harm to persons or environment. Risks associated with the operation and maintenance of an asset has to be identified according to a process so that it can be properly managed and mitigated. Many organizations make use of outside assessing authorities to determine the level of conformance to the SHER issues and for the purpose of an Asset Management audit this assessment does not need to be repeated. The results of the last audits can be used for the overall findings.

### **3.2.2.13 Control and Automation**

The control and automation of assets is advancing at a fast pace. Less and less human intervention is required which can contribute to improved performance of the assets. SCADA systems, PLCs and other instrumentation assist in automating and controlling an asset in the plant process by the click of a button. In this element it is important to ensure that the correct systems and instrumentation are deployed to support the control and automation of assets optimally.

### **3.2.2.14 Operating Instructions/Procedures**

This was touched on earlier and is a very important element to ensure the correct operation and care for the asset. Sometimes an operator takes charge of a multi-million dollar asset. The correct instructions/procedures and autonomous maintenance tasks must be carried out by the operator and ownership of the asset transferred to him/her. If the operator of the asset does this correctly the asset can be expected to perform well. This will typically include processes and tools for example, TPM (Total Productive Maintenance) and other philosophies to optimize the discipline of operating an asset.

### **3.2.2.15 Technology Management**

Technology is advancing at a blistering pace. With technological advances, efficiency and cost improvements can be brought about. It is necessary to keep abreast of new technology that can support and improve the way we do business in an organization. It can mean improved business processes, improved equipment, improved systems and even improved human development. This must be an important part of Asset Management as a whole and of the continuous improvement effort.

### **3.2.3 Asset Disposal**

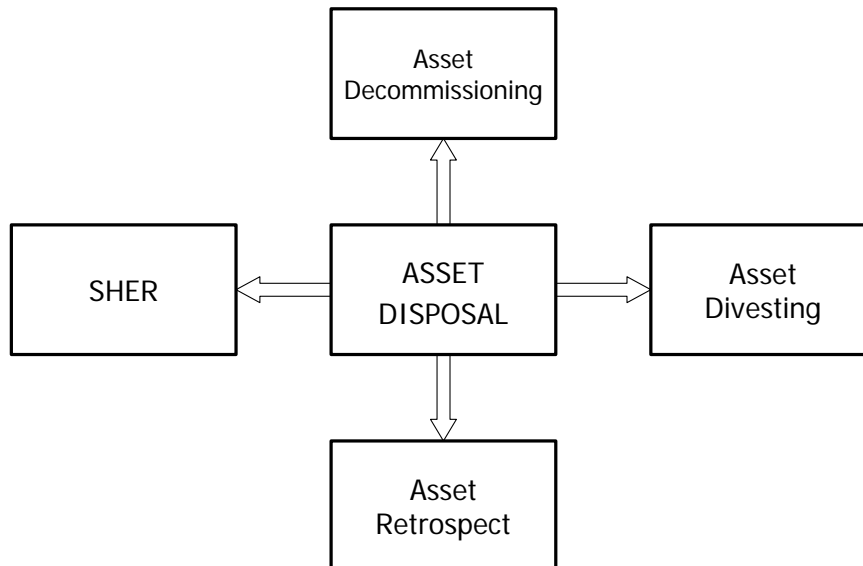
The final phase in the life cycle of an asset, namely Asset Disposal, is illustrated in Figure 13 with different elements representing the business processes that can be managed in this part of Asset Management.

#### **3.2.3.1 Asset Decommissioning**

When an asset has reached the end of its economic life or the need for the asset by the organization has lapsed, the asset will need to be decommissioned. The process to perform this decommissioning need to be managed properly to make sure that it is done in an orderly and safe manner. When an asset is decommissioned the Change/Modification Management process has to be initiated so that the relevant systems and documents can be updated. This is a phase in the life cycle of an asset that is often neglected and therefore would need rigorous tracking and control to ensure proper execution.

#### **3.2.3.2 Asset Divesting**

The opportunity can still exist to get some form of return from an asset after it has been decommissioned. This can be in the form of auctioning off the asset or advertising it in the market place. Provision must be made for this opportunity in the business process of asset disposal.



**Figure 13: Asset Disposal framework/model**

### **3.2.3.3 Asset Retrospect**

It is important to reflect on the performance of the asset after it has been decommissioned, especially if the same or similar asset is still in operation or planned to be acquired. This can give valuable information related to the productivity-, economic- and integrity performance of the asset. It will allow comparison to other makes and models of similar equipment, whereby the best performing asset can be utilized. This can also support informed decision making on the acquisition and deployment of same or similar assets in the future.

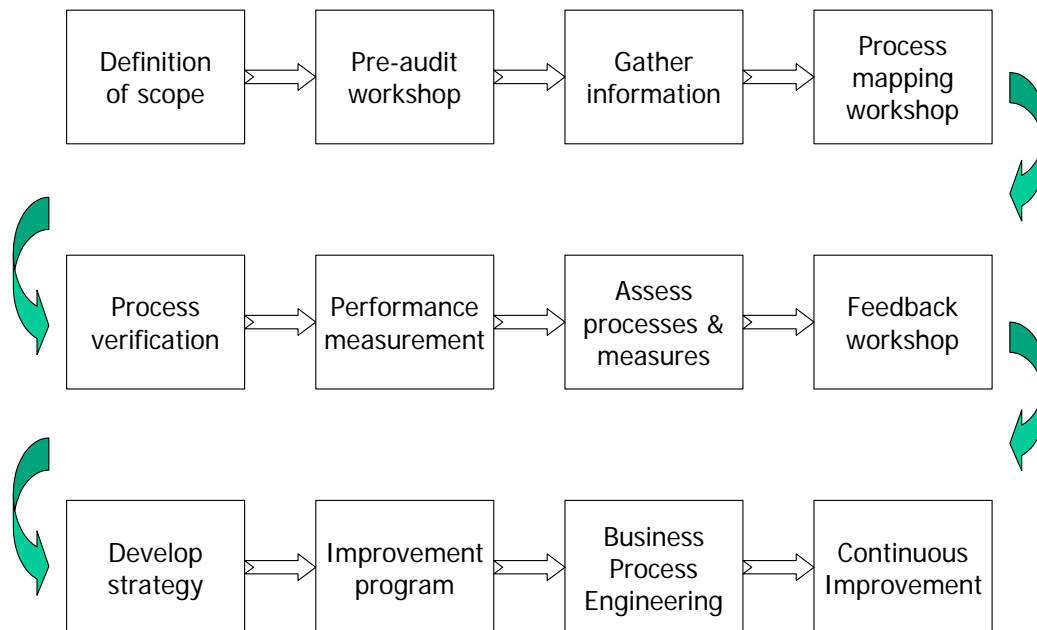
### **3.2.3.4 Safety, Health, Environment and Risk (SHER)**

When disposing of an asset there may be certain regulations, environmental or health issues that need to be addressed and conformed to. Permits for operating pressure vessels, for example, should be returned to the relevant government authorities and indicated that the particular pressure vessel is not in operation anymore. When disposing of certain assets care must be taken that the environment is not affected in any way.

This newly developed framework will serve as the basis for the Asset Management Audit. The maturity will be assessed in each of these elements to give an indication of the opportunities within each of them.

### 3.3 Asset Management Auditing Methodology

Different methodologies to conduct an audit have been researched and presented in Chapter 2. A new methodology, that includes the concept of Business Process Engineering, is shown in Figure 14. As part of the audit methodology, business processes are identified, mapped and assessed according to the developed framework for AM.



**Figure 14: Asset Management Audit methodology**

A description of each of the steps in the methodology for conducting this audit follows:

#### 3.3.1 Sponsor/Management Definition of Scope

Management or the identified sponsor defines the scope of the audit together with the Auditor. The framework, as discussed earlier, consists of elements and a decision has to be made whether certain of these elements will be excluded. Additional elements may be proposed if there are certain issues that Management or the Sponsor feel should be addressed and are not highlighted in the baseline framework.

#### 3.3.2 Pre-Audit Workshop

Before the audit is conducted a pre-audit workshop is conducted with the key role-players from the section. It is important to include representatives from all affected departments and levels in the organization. The scope and methodology of the audit is presented and discussed. It is important that the audience understand why the audit is being conducted and to gain their support.

### **3.3.3 Information Gathering**

According to the decided scope, information on the relevant elements is gathered. This information includes the current processes in each element in the form of policies or procedures as well as the supporting systems and tools. Examples of documents or transactions should be provided as well as copies from logbooks or other manually updated systems. To enable the auditor to perform a proper assessment he will need all the relevant information and it is best to determine before the audit what information will be needed. With this information, and what is gathered from the physical audit, the auditor will be able to perform a proper assessment.

### **3.3.4 Process Mapping Workshop**

This step is different from the ordinary run-of-the-mill audits. After the information has been gathered and the auditor identifies that there are certain processes that he could not be supplied with (because it has never been documented), he should facilitate a short workshop to map the outstanding processes. For example, the process of reviewing a maintenance plan has never been documented and the auditor could not be supplied with the process. The auditor calls a workshop and involves the key stakeholders where he will enquire into how “currently” maintenance plans are reviewed. At this stage no effort should be made to analyse the effectiveness of the processes that was mapped. It may also be found that the required process does not exist.

### **3.3.5 Process Verification**

This can be compared to the physical audit of “traditional” audits. The auditor will visit the section and question certain key personnel on the execution of the processes in the workplace.

You may find that a business process has been documented in the form of a procedure, governing the execution thereof, but that in the day to day situation in the workplace it is executed differently from what is prescribed. The auditor may also enquire into why it is done differently in order to identify any shortcomings in the process. The systems that support these business processes, e.g. CMMS, materials ordering system, financial system, also need to be evaluated for effectiveness and efficiency.

### 3.3.6 Performance Measurement

Organizations and even sections within organizations have different ways of calculating the same measurement. A simple measure, like availability of assets, has been found to have various different formulas for calculation. It is therefore important that the auditor develop a set of key metrics with set formulas to be able to measure the performance of the organization. The different elements of the audit framework should have a least one or two measures assigned to it to enable comparison to benchmarks.

### 3.3.7 Assessment of Processes and Measures

After the auditor has gathered all the information he requires he will be able to assess and appraise the organization’s level of maturity in each of the elements. A guideline for assessing the business process maturity is shown in Figure 15.

Level 1	Level 2	Level 3	Level 4	Level 5
The business process (BP) does not exist	Business process exist, not documented, no training in BPs, not been improved in previous few years	Business process exists, is documented and communicated in form of policy or procedure, readily available and understandable. Some revisions done in previous year.	Business Process training is performed, roles and responsibilities of individuals according to it. Systems support 80% of BPs.	BPs has been modelled with ongoing BP Improvement initiative. Integrated across functional and departmental boundaries. All elements in AM covered by BPs.

**Figure 15: Five Levels of Maturity for Business Processes within Asset Management**

An example of some Key Performance Indicators (KPIs) and benchmarks that can be used is illustrated in Figure 16.

Element	Metric	Level 1	Level 2	Level 3	Level 4	Level 5
Asset Maintenance: Maintenance Tactics	Planned vs Unplanned maintenance hours ratio	40:60	50:50	60:40	70:30	80:20
Asset Maintenance: Materials Management	Stores value vs Equipment Replacement Value	4%	3.5%	3%	2.5%	2%
Asset Maintenance: Financial Management	Maintenance Cost vs Equipment Replacement Value	8%	6.5%	5%	3.5%	2%
Asset Maintenance: Work Management	Labour Utilization (Wrench time)	45%	50%	55%	60%	65%

**Figure 16: Five Levels of Maturity for Performance Measures in Asset Management**

According to the findings of the auditor the maturity of performance and practices of the organization can be mapped on these matrices. This allows for scoring and determining the average level of maturity in each element and Asset Management as a whole.

### 3.3.8 Feedback Workshop

The feedback workshop should involve all the key personnel that were involved in the audit as well as a representative from different levels and departments. A summary of the outcome of the audit must be presented and discussed in this session. Questions and comments can be addressed. The auditor must highlight positive areas, areas of concern and opportunities. A full report can also be distributed during this session. A re-look at the auditing methodology progress and next steps will conclude the session.



### **3.4 The “Roadmap” to Asset Management Excellence:**

#### **3.4.1 Strategy Development**

When developing the Asset Management Strategy, representation from all key stakeholders is imperative. This stays important to ensure that the necessary support and buy-in is gained from the people that are going to make it work. Opportunities for improvement have been identified by the audit and according to this the strategy will be developed.

Firstly, the Vision and Mission of the team is set, describing the desired future state.

A typical Vision can be “The organization will be a world class competitor within Asset Management”. A mission might be as follows; “To maximise the profitability of the organization’s physical assets”.

Secondly, certain values or principles that will guide the conduct of the team within Asset Management can be set to ensure the correct mindset, ethic and culture is maintained. An example of a value can be; “The organization will pride itself in effective communication and sharing across functional boundaries” or “An open door policy will be maintained”.

Thirdly, the different elements of the framework or model are prioritized and the current state (“as-is”) is displayed and a group decision on the future state (“to-be”) has to be taken, with a time frame, in which to reach it. This is done on a high level only, per element of the framework, according to the maturity level index.

Fourthly, objectives can be set for the elements that will describe the future state in detail. For example, an objective can be “To instil a culture of fault-finding and elimination in the workforce” or “Apply the optimum maintenance mix on our assets”. Together with developing the objectives, Key Performance Indicators can be set which will be able to indicate if the objectives have been achieved. It is not advisable to institute too many different measures that can become a tedious task to update and control. Chances are that what was set out to achieve will not be realized because of just too many things to focus on. Rather, assign one or two measures per element and spent the effort on driving those (it can be the measures used in the audit). Of course, targets need to be set for these KPIs and when setting the targets make sure that benchmarks are taken into account.

### **3.4.2 Improvement Program**

The gaps have been identified, targets have been set and the *Program for Asset Management Improvement* (PAMI) has to be developed. This program will contain the plans to close the gaps and achieve the targets. PAMI is a living program that details all the necessary actions, resources and timelines that will take the organization to the desired future state. When scheduling the program, the priority of planned actions is taken into account. Commitment on this program from all levels in the organization is required to make it work. Barriers to realising the benefits, by implementing this program, must be identified and dealt with. The asset and process owners must make this their own and drive it on a continuous basis. PAMI can be captured on a Gantt chart format, which allows the allocation of time and resources to each activity and the updating of progress. PAMI needs to be communicated and displayed to all stakeholders so that current and future actions can be visible to all concerned. A regular progress review meeting should be instituted to address problems or concerns.

### **3.4.3 Business Process Engineering**

Tritter [21] postulates that the entire organization can be seen as a set of processes. Asset Management can therefore also be seen as a set of processes with systems that support these processes. The PAMI will show that the actions listed in some form or another can be related back to certain business processes. It can for example be the process to handle a breakdown, the process to acquire a spare part or the process of improving the competency of a person. Therefore a definite link exists in improving Asset Management by improving the business processes that constitutes Asset Management. Now, there are various different tools and methodologies in the industry to perform Business Process Engineering. Some of these have been mentioned in Chapter 2 and includes the *Business Process Re/Design* from Malhotra [20], *Control Self-assessments* from Tritter [21] and *Process Reengineering Life Cycle* by Grover [22], to name but a few. The organization will have to review the different methodologies available to perform Business Process Engineering and adopt what is most suited for the organization. At this stage it is very important to formally exercise Change Management in the organization. Volumes of literature have been written on the subject and if done properly can ensure that the new, improved practices is accepted by the organization.

#### **3.4.4 Continuous Improvement**

The Asset Management Audit is not a once off exercise. It is advisable to perform follow up audits to assess the implementation of the improvement actions as well as the effectiveness thereof. This follow up audit should be based on the PAMI and can be done six monthly. The full Asset Management Audit as described above can be administered on an 18 to 24 month basis. Westerkamp [23] states that audit information focuses attention on improvements; it can compare your operation with the best. Questions raised can include – How much will it be worth to turn weaknesses into strengths? How do you do it? In what priority? Answers to these questions are vital to effective management. Westerkamp [23] postulates the audit helps to answer these questions and more. As you apply the audit process and compare trends with past audits, you gain increasing knowledge about the dynamics of your organization. You have in place a continuous improvement program.

Asset Management has been defined to clarify the scope. A comprehensive framework or model for Asset Management has been developed and presented that can be used for conducting the audit. The methodology for conducting the Asset Management audit has been described and reference made to the importance of Business Process Engineering. The process of developing the “roadmap” to Asset Management Excellence was presented.

#### **3.5 Hypotheses**

The expectation of the above theory is that an Asset Management Audit methodology will increase the asset management performance of a company.

## **CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY**

### **4.1 Research Strategy**

The strategy to perform the research was structured as follows:

#### **4.1.1 Theory Building Research (60%)**

Studying past and current theory as well as developing new theories researched a new or improved model and method for Asset Management auditing. Various articles, textbooks and websites have been consulted to gather information on different Asset Management related topics. These topics included Maintenance Management, Audit methodologies, Business Process Engineering and Asset Management methodologies and models. Various definitions for Asset Management as well as frameworks or models that represent the scope of Asset Management were researched. After considering all of the different definitions, a new definition for Asset Management was formulated to clarify the concept of AM. The different frameworks and elements of the frameworks from the different sources were grouped into the four life cycle phases of an asset (according to the definition), which were the new high-level framework for Asset Management. The consolidation of all the different elements and adding some new elements resulted in a comprehensive Asset Management framework that can now form the basis of the audit. Different audit methodologies were also researched and found that certain steps or processes could be added to ensure more value is derived from an audit. This resulted in Business Process Engineering being included in the new auditing methodology and research was performed to gather information on some of the methodologies and tools to conduct Business Process Engineering or Reengineering. An example of a maturity matrix for Business Processes and Performance Measures were also established in order to appraise the relevant business processes and performance of the organization in the different elements.

#### **4.1.2 Theory Testing Research (20%)**

The newly developed method and model was tested by compiling a survey questionnaire (see Appendix B) to test the hypothesis. This survey was conducted across the De Beers group of companies.

Five different questions were raised in the questionnaire to address the relevance and quality of the developed definition, framework and auditing methodology. The perceived value add to an organization by performing this audit and following the developed methodology was tested in the survey.

#### **4.1.3 Theory Application Research (20%)**

The theory was applied in a practical environment within an organization through conducting a physical Asset Management audit. The Final diamond recovery plant of Jwaneng Mine in Botswana was chosen as the pilot site to conduct an audit according to the new auditing methodology. Management and relevant stakeholders were involved from the start and the methodology described in detail. The audit was conducted from 13-24 September 2004 and involved all the departments and different levels in the Plant according to the framework and methodology of the audit. The results from the audit are summarized in Appendix A.

#### **4.2 Research Methodology**

The methodology applied was based on the logic for theory-based empirical research. The technological/industrial or organizational environment was scanned to determine the background and current state of Asset Management Auditing and to identify what the research problem may be. The review of past research and current theories, models and methods were conducted. If a theory gap was believed to exist, this gap was quantified. The deduction of a new proposition, through a methodological study, was combined with a working hypothesis for the expected results. Extensive gathering of data on the specific and related fields were undertaken and the acquired data analyzed. Through practical application and testing the hypotheses will be validated. If the new theory was supported the study was complete, if not the interference of new hypotheses needed to be initiated. This could have led to the introduction of new theory, models or methods.

#### **4.3 Research Instruments**

Literature and data on the subject of Asset Management as well as related subjects were acquired from:

- Text books

- Course materials
- Libraries
- Technical journals and papers
- Conference proceedings
- Consultants in the field
- Internet websites
- Company and other Organization's practices

The validation of the developed theory, method and model were done through:

- Survey distributed to different representatives within the De Beers group of companies as well as certain field specialists.
- A practical application (case study) was also conducted to validate the hypotheses.

## **CHAPTER 5: RESULTS: DATA GATHERED AND ANALYZED**

### **5.1 Data Gathering Process**

Data was gathered through two processes: The practical application of the newly developed methodology to conduct a physical Asset Management Audit and the distribution of a survey questionnaire on the definition, framework and auditing methodology that was developed. A discussion of both the data gathering processes follows:

#### **5.1.1 Practical Application**

The auditing methodology as discussed in 3.3 of this report was applied on the Final Recovery Plant at the Jwaneng Diamond Mine in the southern part of Botswana. Jwaneng Mine, the richest diamond mine in the world, produced 12 million carats in 2003. Its sister operations are based in Orapa and Letlhekane in the northern part of Botswana. The Final Recovery Plant has been zoned as the Red Area due to the high security risk associated with the final recovery of diamonds, hereon after the plant will be referred to as the Red Area.

According to the process described in 3.3 the first step was to determine the scope of the audit. Members of the management team at the Red Area met and the following representatives were present:

- Plant Manager
- Asset Management Engineer (Auditor)
- Senior Planning Foreman (Auditor Assistant)
- Assistant Plant Superintendent
- Section Engineer (Electrical and Mechanical)
- Section Engineer (Instrumentation)
- Maintenance Planning Foreman
- Senior Technician and
- Engineering Foreman.

The decision was made, due to several reasons, to limit the scope to the following eight elements of the Asset Management Framework as discussed in 3.2:

- Strategy Management
- Maintenance Tactics
- Work Management
- Human Resources
- Performance Measurement
- Continuous Improvement
- Materials Management and
- Systems & Information

The next step was to invite the management team as well as representatives of the different departments and levels to the Pre-audit workshop. This was in the form of the presentation where the scope of the audit was communicated and the purpose of the audit clarified to those present. Any question about the audit was entertained to create better understanding and buy-in.

The information gathering process ensued where the information on the different elements was gathered through the following:

- A list of documented information required was given to the Maintenance Planning Foreman to collect and present to the auditors in a file.
- Discussions with the process owners were held whereby pertinent questions were raised on the different elements of the framework and the business processes in each.
- A list of typical business processes in each element of the scope was created.

After comparing the information received and the list of typical business processes, the outstanding business process with no information was identified and a short workshop held to map the current process.



With this information the scheduled interview sessions was conducted with all the stakeholders to question and investigate the application of the business processes. Standard questions were used and proof of statements made by the interviewee was required. Observation of business processes in practice was done by the auditors and notes made on deviations and opportunities.

The actual performance of the Red Area was then calculated according to the set measures for each of the elements in the scope of the audit.

The performance and maturity of the business processes of the Red Area was then assessed and scored according to the five levels of maturity for business processes within Asset Management (Figure 16) and the five levels of maturity for performance measures in Asset Management (Figure 17).

The observations and recommendations were compiled in a report, distributed and presented to the stakeholders at a feedback workshop. It was made clear that the right to appeal exists and that the audit was a snapshot at a point in time.

The Asset Management strategy and improvement program was reviewed with regards to the finding of the audit.

### **5.1.2 Survey**

A questionnaire (Appendix B) was drawn up to test the new model and methodology in the field. The questionnaire consisted of the following five statements:

- a. The definition for Asset Management as quoted in 3.1 of the article describes the concept of physical Asset Management clearly, considering the whole life cycle of assets.
- b. The elements of the developed framework, for Asset Management, address most of the possible elements/business processes within a typical organization as described in 3.2.
- c. The Framework is simplistic and easy to understand (down to Supervisor level).
- d. The Asset Management Audit methodology described in 3.3 is practical and could easily be applied to your organization
- e. The application of the Asset Management Audit methodology should have the potential to positively affect the profitability or success of an organization.

The questionnaire was distributed within the De Beers group of companies and addressed to persons that are directly involved in the field of Asset Management. A list of the targeted sites is shown below:

- Debswana – Jwaneng Mine
- Debswana – Orapa Mines
- Debswana – Head Office
- De Beers – Premier Mines
- De Beers – Head Office
- De Beers – Finsch Mine
- De Beers – Venetia Mine

The respondents were asked to indicate to each statement the degree of agreement according to three levels:

- Fully agree
- Partially agree
- Disagree

Comments to each of the responses from the assessor on the statements were also requested to motivate the choice made.

## **5.2 Data or Information Gathered**

From the practical application a list of the chosen elements that represents the scope of the asset management audit conducted at the Red Area of Jwaneng Mine is listed with the relevant business processes allocated to each element. A list of the Key Performance Indicators allocated to each element to measure the performance of the Red Area was also compiled and calculated. The final report of the Asset Management Audit conducted is attached as Appendix A. The answer to various questions was noted on sheets during the

session with each of the interviewees. The feedback from the survey was compiled on one report with the averages and comments consolidated.

### 5.2.1 Practical Application

As shown in Figure 17, the scope of the audit with each of the elements is shown. For each of the elements typical business processes were identified and are also shown in Figure 17.

<b>Element</b>	<b>Business Process</b>
Strategy Management	<ul style="list-style-type: none"> <li>▪ Strategy development</li> <li>▪ Strategy implementation</li> <li>▪ Improvement Program</li> </ul>
Performance Measurement	<ul style="list-style-type: none"> <li>▪ PDR (Plan, Do, Review)</li> <li>▪ Benchmarking</li> <li>▪ Key Performance Indicator development and reporting</li> </ul>
Continuous Improvement	<ul style="list-style-type: none"> <li>▪ Suggestion Scheme</li> <li>▪ Root Cause Analysis &amp; Problem Solving</li> <li>▪ Balanced Score Card</li> </ul>
Systems & Information	<ul style="list-style-type: none"> <li>▪ Knowledge Management</li> <li>▪ Library Control</li> <li>▪ Change/Modification Control</li> </ul>
Work Management	<ul style="list-style-type: none"> <li>▪ Unplanned Work Control</li> <li>▪ Planned Work Control</li> <li>▪ Shutdown Management</li> </ul>
Human Resources	<ul style="list-style-type: none"> <li>▪ Performance Management system</li> <li>▪ Personnel Development</li> <li>▪ Workforce Complement planning</li> </ul>
Maintenance Tactics	<ul style="list-style-type: none"> <li>▪ Maintenance Plan Design</li> <li>▪ Maintenance Plan Review</li> <li>▪ Criticality analysis</li> </ul>
Materials Management	<ul style="list-style-type: none"> <li>▪ Spares/Materials acquisition</li> <li>▪ Rotable/Refurbishable Assets Control</li> <li>▪ New Stock application</li> </ul>

**Figure 17. Typical Business Processes within the elements**

The different measures for each of the elements were calculated and the results are shown in Figure. 18 below.

Element	Metric	Level 1	Level 2	Level 3	Level 4	Level 5
Asset Maint&Ops: Strategy Management	Asset Management maturity (audit result)	<20%	20-39%	40-59%	60-79%	>79%
Asset Maint&Ops: Strategy Management	Compliance to PAMI (Act. progress vs Plan)	<70%	70-79%	80-89%	90-99%	>99%
Asset Maint&Ops: Performance Measure	Overall Equipment Effectiveness	<60%	60-69%	70-79%	80-89%	>89%
Asset Maint&Ops: Performance Measure	% Objectives/Targets planned achieved	<70%	70-79%	80-89%	90-99%	100%
Asset Maint&Ops: Continuous Improvement	% *Incidents subjected to formal RCA and PS	<20%	20-39%	40-59%	60-79%	>79%
Asset Maint&Ops: Continuous Improvement	% RCA Solutions successfully completed	<60%	60-69%	70-79%	80-89%	>89%
Asset Maint&Ops: Information Management	Data Integrity accuracy assessment	<80%	80-84%	85-89%	90-95%	>95%
Asset Maint&Ops: Information Management	Statistical Analysis completed: % of *assets	<20%	20-39%	40-59%	60-79%	>79%
Asset Maintenance: Work Management	Labour Utilization (Wrench time)	<45%	45-49%	50-54%	55-60%	61-65%
Asset Maintenance: Work Management	*Master Schedule Completion	<80%	80-84%	85-89%	90-95%	>95%
Asset Maint&Ops: Human Resources	Competency Profile coverage	<60%	60-69%	70-79%	80-89%	>89%
Asset Maint&Ops: Human Resources	Individual Performance Contracts coverage	<60%	60-69%	70-79%	80-89%	>89%
Asset Maint&Ops: Maintenance Tactics	Uptime :Planned DT: Unplanned DT ratio	70:3:27	75:4:21	80:5:15	85:6:9	90:7:3
Asset Maint&Ops : Maintenance Tactics	Planned vs Unplanned maint. hours ratio	40:60	50:50	60:40	70:30	80:20
Asset Maint&Ops: Materials Management	Stores Turnover	<1	1 - 1.5	1.6 - 2	2 - 2.5	>2.5
Asset Maint&Ops :Materials Management	Stores value vs Equipment Replacement Value	>5%	4 - 4.9%	3 - 3.9%	2 - 2.9%	<2%

**Figure 18. Performance Measures results**

Element	Business Process	Maturity Level				
		Level 1	Level 2	Level 3	Level 4	Level 5
Strategy Management	▪ Strategy development					
	▪ Strategy implementation					
	▪ Improvement Program					
Performance Measurement	▪ PDR (Plan, Do, Review)					
	▪ Benchmarking					
	▪ Key Performance Indicator development and reporting					
Continuous Improvement	▪ Suggestion Scheme					
	▪ Root Cause Analysis & Problem Solving					
	▪ Balanced Score Card					
Systems & Information	▪ Knowledge Management					
	▪ Library Control					
	▪ Change Management					
Work Management	▪ Unplanned Work Control					
	▪ Planned Work Control					
	▪ Shutdown Management					
Human Resources	▪ Performance Management system					
	▪ Personnel Development					
	▪ Workforce Complement planning					
Maintenance Tactics	▪ Maintenance Plan Design					
	▪ Maintenance Plan Review					
	▪ Criticality analysis					
Materials Management	▪ Spares/Materials acquisition					
	▪ Rotable/Refurbishable Assets Control					
	▪ New Stock application					

**Figure 19. Business Process Assessment results**

Each of these business processes was mapped and assessed according to the maturity levels as defined in Figure 16 of Chapter 3. In Figure 19 the business process assessment results are shown.

The final report is attached as Appendix A and contains the Positive Points and Opportunities identified during the audit.

### 5.2.2 Survey

The survey questionnaire feedback on each question was as follows:

Question 1:

“The definition for Asset Management as quoted in 3.1 of the article describes the concept of physical Asset Management clearly, considering the whole life cycle of assets.”

Fully Agree – 100%

Partially Agree – 0%

Disagree – 0%

Summary of comments:

- Question rose if the ore body as an asset also fits into the definition; this definition only covers physical assets (equipment or structures) and does not include the ore body.
- To further allay confusion, the term Physical Asset Management should be used to distinguish between other forms of Asset Management.
- Referring to operation and maintenance as separate life cycle phases but they are one and the same in time, only two different processes as illustrated.

Question 2:

“The elements of the developed framework, for Asset Management, address most of the possible elements/business processes within a typical organization as described in 3.2.”

Fully Agree – 57%  
Partially Agree – 43%  
Disagree – 0%

Summary of comments:

For the 43% that responded in partially agreeing, the following comments were made and an appropriate response made by the author:

- “This seems to be a purely engineering function” – That is exactly why the operation phase has been included to not only focus on Maintenance Management but move towards Asset Management that will include the operational phase.
- “No mention of tools and workshops” – Careful reading will reveal that tools and workshop has been included under the element “Work Management” as it is an integral part of this element.
- “Would prefer to see a fifth dimension, that of operational readiness, an asset taken through from being acquired to operational phase” – The element of Asset Acquisition with its sub-elements focuses on this in detail, addressing the comment that the respondent made.
- “Asset Retrospect from the Asset Disposal element, shouldn’t it feature under the Continuous Improvement or Maintenance Tactics sub elements?” – Asset Retrospect will be done as part of the Asset Disposal phase to ensure that all the learning and information on the performance of the asset is analysed to guide future investment in the particular asset.

Question 3:

“The Framework is simplistic and easy to understand (down to Supervisor level).”

Fully Agree – 57%

Partially Agree – 43%

Disagree – 0%

Summary of comments:

- “Language may need simplifying, and concepts explained more” – As part of the auditing methodology the introduction and feedback workshops as well as the interaction during the audit will be used to transfer the knowledge on the concepts and terminologies used in Asset Management.
- “Framework is simplistic if Supervisors/Engineers have some background in asset management” – Comment as above applies
- “Some study of the concepts involved will have to be carried out to fully understand their meaning” – Comment as above applies

Question 4:

“The Asset Management Audit methodology described in 3.3 is practical and could easily be applied to your organization.”

Fully Agree – 43%

Partially Agree – 57%

Disagree – 0%

Summary of comments:

- “Key concern would be to address the readiness for change, maybe this step could be included early in the process” – Change Management is referred to in the paper and the importance highlighted, but the objective of this paper was not to research change management. The focus was on the auditing methodology and the technical framework. Change Management will have to be applied throughout any improvement initiative.



- “Why cannot the same framework be applied to each of the phases individually, the level of maturity in each of the phases will be different and this may be masked by making the audit too broad” – As clearly mentioned in the paper, the scope of the audit will be determined by the management of the area to be audited, this is the first step in the audit process. The framework as determined in this report only provides a holistic scope of all the elements within asset management. There is no rule that all elements must be included in all audits!
- “The audit seems upon casual observation to be a bit time consuming with many workshops. If this is used for a high-level company wide audit it might be practical, but not for smaller compliance audits” – The statement made above also applies for this comment.
- “I would have liked to see some typical audit statements” – The auditing methodology was the focus in this research, the assessment of business processes and measures is key to the methodology and therefore typical statements can be developed around assessing the processes and measures.
- “AM should have a strong business orientation and whatever framework is used, should support and incentivise Business Value Add within an Asset Life-cycle context” – The goal of Asset Management is that of improving or optimizing the profitability or success of an organization through proper Asset Management.

Question 5:

“The application of the Asset Management Audit methodology should have the potential to positively affect the profitability or success of an organization.”

Fully Agree – 86%

Partially Agree – 14%

Disagree – 0%

Summary of comments:

“Auditing is a management tool addressing the need for assurance, much more than it is a strategy implementation vehicle. It cannot circumvent investment in people etc. but admittedly enhance the success of these investments by assuring basics are and stay in place”  
– The Asset Management Audit is a tool to assess the organizations maturity in Asset Management and provide a baseline on which the improvement strategy will be based, but without action the audit will mean nothing.

### **5.3 Data Analysis**

Data collected from the practical application and the survey questionnaire was analysed and the following found:

#### **5.3.1 Practical Application**

The auditing methodology developed and applied at the Red Area, Jwaneng Mine, was applied successfully and the stakeholders of the Red Area bought into and supported the new auditing methodology. The results from the audit were regarded as accurate and were accepted by the management team as well as other stakeholders.

#### **5.3.2 Survey**

The results from the survey indicate that the new auditing methodology is accepted and supported, as well as the framework and elements identified as the scope of Asset Management. Most of the partial agreements could not be validated, as it seemed that the respondent either did not understand or misinterpreted the report. The biggest concern highlighted by the participants was that the audit may be too holistic, but it is made clear that the first step of the audit is to determine the scope. Obviously when this step is performed the environment where the audit will take place must be taken into consideration and this will ensure that the scope of the audit is then applicable for the specific application and not too broad.

#### **5.4 Hypotheses Testing**

The expectation of the theory developed was that an Asset Management Audit methodology would increase the asset management performance of a company. Judging by the results from the practical application and the survey conducted this hypotheses has been proven to be true.

## CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Research Results

The main objective of the research – to develop a new, improved Asset Management Auditing methodology – has been achieved. Including the principle of Business Process Engineering made the most important development or contribution. Any organization is made up of many different Business Processes in various levels, from high-level processes with sub-processes down to the individual task level. This is also the case for the discipline of Asset Management. Regarding Asset Management as a set of business processes and performing the audit to assess and evaluate the business processes is a very important principle that was highlighted by this research. The process to develop an AM strategy and the Program for Asset Management Improvement (PAMI) is a very important phase of the audit to ensure that the opportunities identified during the audit is addressed and actions put in place to achieve the desired improvements. The utilisation of tried and tested Business Process Engineering tools and methods, examples include the *Business Process Re/Design* from Malhotra [20], *Control Self-assessments* from Tritter [21] and *Process Reengineering Life Cycle* by Grover [22], to name but a few, to assist in realising the improvement is a valuable contribution to the science of Asset Management.

The supporting objectives, namely, developing a definition for Asset Management and a comprehensive framework with elements constituting the scope of AM have been achieved.

### 6.2 Implications for and/or Contributions to Theory and Practice

Any organization can adopt and apply the auditing methodology. The practical application has proven successful at the Red Area, Jwaneng Mine. The methodology as described in 3.3 and Figure 14 establishes a sound process and a valuable tool to assess the current performance of an organisation's Asset Management practices and processes. Thereby several opportunities will be identified (within the predetermined scope of the audit) at the organisation. The manager or person responsible for the performance of the assets can now obtain a clear picture of the current state of Asset Management. Some of these opportunities may otherwise not have been identified. The methodology not only focuses on the physical audit but also the improvement process that follows an audit. In many instances this has been neglected and

therefore very little or no improvement took place after an audit. With the methodology that has been developed in Figure 14, the process of creating a Strategy and a Program for Asset Management Improvement will contribute to improve the performance of the assets and the maturity of Asset Management. By utilizing the principles of Business Process Engineering, also included in the developed methodology of Figure 14, it will further ensure effective and efficient processes and management of physical assets. By applying the principle of Business Process Reengineering radical improvements can be expected as the business processes constitutes the work/activities taking place within an organisation. Ultimately, the application of the newly developed AM auditing methodology will contribute to the practice by improving performance of physical asset that in turn can influence the profitability of the organization. That remains the goal of any initiative for improvement that is also supported by the developed methodology. Contribution to the theory of AM was achieved through the development of the definition for Asset Management; this should now clarify what the principle of Asset Management constitutes. The framework and elements, referred to in Section 3.2 and Figures 10-13, constitutes the scope of Asset Management and this also adds to the theory and indeed the practice of what should be included in the science of Asset Management. It defines the various issues that should be addressed through Asset Management during the life of a physical asset.

### **6.3 Self Assessment**

Developing a definition of Asset Management, a framework and auditing methodology that will also include the “roadmap” to AM excellence have achieved the objectives of the research. This “roadmap” is laid out in the form of the Program for Asset Management Improvement. Through a practical application and the administration of a survey the hypotheses and principles on which the research was based, was proven.

### **6.4 Recommendations**

Further study is proposed to research and develop business processes for the different elements of the framework. For example, in the Maintenance Tactics sub-element of the Asset Maintenance element, the business process of Maintenance Plan Design/Development can be researched for the most effective and efficient process of performing this analysis. This can be

a generic process that can be applied to most organisations without significant changes and should represent a “best practice” at that stage.

Another area that need to be addressed and has been highlighted as a concern by some of the participants of the survey is that of Change Management. The challenge of changing human behaviour to accept and apply new or changed practices and process will be a critical success factor of implementing the desired improvements. This principle applies in any field and not only Asset Management. Many literature sources are available on the subject and there might be value in researching an optimum method or model to apply to an organisation in the process of implementing AM improvements.

Developing a comprehensive list of Key Performance Indicators within each of the elements of the new Asset Management framework can also contribute to the science of Asset Management. A standard calculation of these KPIs need to be formulated, ensuring a uniform measurement of Asset Management performance.

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## Appendix A: Asset Management Audit Feedback Report



Asset Management Audit

# Feedback Report

For

# Jwaneng Red Area Section

Audit date: September 2004

Compiled by: Freddie Mollentze

## Executive Summary

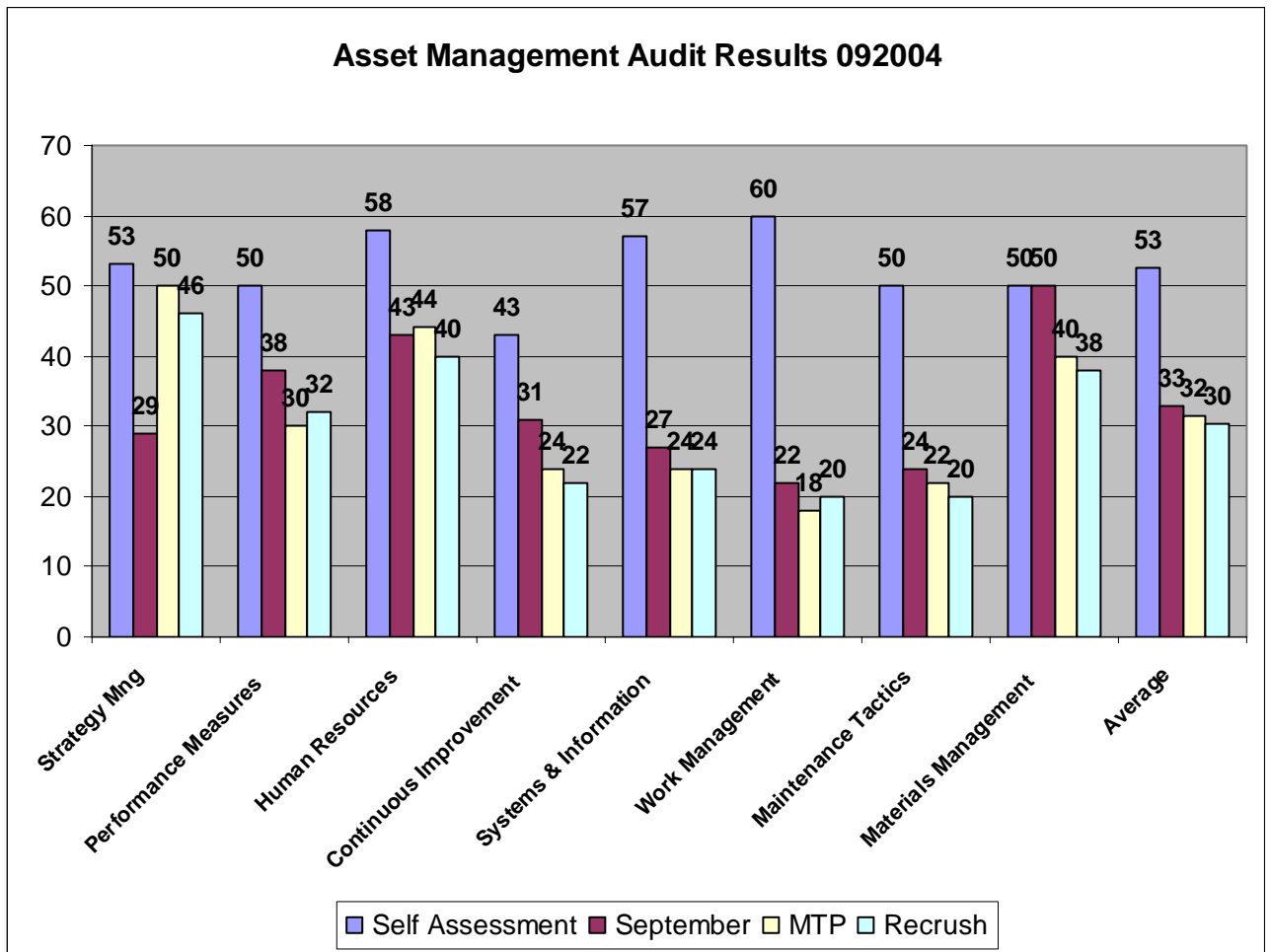
An Asset Management audit was performed at DEBSWANA Jwaneng Mine (Red Area) in September 2004.

The major findings are summarised below:

<b>Average score</b>	33%
<b>Asset Management Maturity Level</b>	Transition from Stabilising level to Preventing level
<b>Suggested major focus areas for the next 3 months</b>	<ul style="list-style-type: none"> <li>• Review the Asset Management Strategy and improvement plan (PAMI) and communicate to all levels and disciplines.</li> <li>• Implement a set of Key Performance Measures at all levels to manage the achievement of the improvement plan (Include measures on BSC).</li> <li>• Ensure that root cause failure information is filled in on job cards/log books and captured on CMMS for future analysis.</li> <li>• Review and document the Maintenance Work Planning and Control Processes and initiate the implementation of the Work Planning and Control Processes.</li> <li>• Implement schedule to review business processes and procedures according to priority.</li> <li>• Develop SLA between different departments and establish proper communication channels</li> <li>• Implement a Maintenance Plan Review Policy</li> <li>• Formalize Problem Solving sessions in line with Knowledge Management process and follow up on corrective action rigorously.</li> </ul>
<b>Suggested major focus areas for the next 6 months</b>	<ul style="list-style-type: none"> <li>• Develop appropriate process to establish/review workforce complement.</li> <li>• Review the Spares Management Processes and initiate the implementation of the Spares Management Processes</li> <li>• Implement the Maintenance Plan Design Processes and initiate the criticality analysis exercise followed by a schedule to design maintenance plans according to priority</li> <li>• Clarify Roles and Responsibilities of all employees according to the business processes and review job descriptions.</li> <li>• Develop training matrix for each section to address skill and competency gaps</li> <li>• Develop comprehensive asset database and hierarchical structure.</li> </ul>
<b>Suggested major focus areas for the next 18 months</b>	<ul style="list-style-type: none"> <li>• Workshop and determine requirements of the CMMS and replace it if necessary.</li> <li>• Implement sub store in the Red Area.</li> </ul>

	<ul style="list-style-type: none"><li>• Develop and implement a proper Change Management procedure.</li><li>• Develop and populate fully the Information system (EB) and ensure all levels are able to utilize it.</li><li>• Implement Life Cycle Costing / Economic Life Determination methodology to optimize life and cost of assets</li></ul>
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Refer to the following graph for a high-level review of the results:



## **Audit Feedback Report**

## 1 STRATEGY MANAGEMENT

### Positive Points

- 1.1 The "2004 Asset Management Strategy" has been developed and is aligned with Central strategy. An Asset Management Improvement Plan exists with accountabilities and due dates.
- 1.2 Balanced Score Card is being used to review operational performance against objectives.
- 1.3 Policies and procedures are easily available on Intranet with most being understood. Some sections brief personnel on the policies and procedures.
- 1.4 Most equipment has a basic PM plan for them.

### Opportunities

- 1.1 Review an Asset Management Strategy taking into account the outcome of this audit. Include all relevant departments and levels to ensure their buy-in and support.
- 1.2 Track the progress on achieving objectives in each Key Performance Area with appropriate Key Performance Indicators on each level in the section.(BSC from Level 1 to 5)
- 1.3 Review the Asset Management Improvement Plan to address the performance gaps identified in this audit. Include detail actions, responsibilities and due dates.
- 1.4 Maintenance needs to be seen as a critical function in the business unit and become a business partner and not only a service.
- 1.5 Review the format of procedures to be more user-friendly and inform all personnel how to access them.
- 1.6 Strategy needs to be communicated and displayed on all levels to ensure that they understand, accept and apply the strategy.
- 1.7 The criticality analysis and optimization of the PM plan for the critical equipment should be a high priority - refer to tactics pillar.



## 2 HUMAN RESOURCES

### Positive Points

- 2.1 Some departments are satisfied with the current organizational structure and updated charts where available.
- 2.2 Staff levels are generally adequate and use is made of contractors to support peak loading and specialized functions.
- 2.3 Most departments are confident in their technical skills.
- 2.4 There are dedicated maintenance planners.
- 2.5 Job descriptions exist for all positions.
- 2.6 Individual performance appraisals system in place for personnel.

### Opportunities

- 2.1 Align the Individual Performance Appraisals, job descriptions and KPIs down to lowest level (use the BSC as a vehicle).
- 2.2 Establish value added communication (problem solving, maintenance and production program alignment, appreciation courses etc.) to improve relations between production and maintenance.
- 2.3 Reduce the effect of parallel reporting between Production and Engineering, according to best practices there should be a common head for maintenance and production as low down as possible in the organization.
- 2.3 Develop RACI matrix for all employees specific to each position.(artisans/technicians cleaning equipment??)
- 2.4 Perform a proper compliment requirement exercise using the forecasted workload to optimize the current labour resources.
- 2.5 Establish training matrices according to individual needs and formally drive on workshop level.

- 2.6 Ensure that all personnel have the necessary technical skills through developing proper competency profiles for all positions and then closing the “gaps” where necessary.
- 2.7 Endeavour to overcome the “Us and Them” culture through developing a Service Level Agreement between Operations and Maintenance (and other departments) to address both department’s needs and deliverables.
- 2.8 Clarify the roles & responsibilities of the planners and also the interfacing responsibilities of other positions (foremen, artisans, production) with regard to work planning and control.
- 2.9 Review the necessity of two Engineers, review compliment of electricians in view of HT switching regulations, additional planning officer to split responsibility of Aquarium and Red Area?
- 2.10 Training officer on site to be the coordinator of all training and also the exposure of employees to new technologies and concepts.
- 2.11 Training of personnel should be followed up and tracked to prove that the skills acquired is being used to the benefit of the company (Ask why are we sending this person on this training?).
- 2.12 Troubleshooting skills for both technical and operational personnel to be improved urgently.
- 2.13 When considering outsourcing ensure that it is necessary and will add value to the organization.

## **5 CONTINUOUS IMPROVEMENT**

### **Positive Points**

- 5.1 An improvement suggestion scheme exists.
- 5.2 An on-the-spot and departmental award scheme is in place.
- 5.3 Most PDRs in place to track corrective actions and accountabilities.
- 5.4 The AM audit performed is a positive step.
- 5.5 Weekly Problem Solving sessions taking place with involvement of different stakeholders.
- 5.6 Allocation of responsibilities for corrective actions done with due dates.
- 5.7 It is perceived that there are adequate resources in terms of people, time and money to support continuous improvement activities.

### **Opportunities**

- 5.1 Review and document the system and process of root cause analysis and problem solving at the weekly high-level session. Taking into consideration the identification of candidate problems (Repetitive / Pareto analysis), starting the session with clear problem statement and structured thinking. Ensure tracking of corrective actions on a weekly basis as part of session.
- 5.2 Review the flow process of the suggestion scheme to allow quicker feedbacks, rewarding and implementation.
- 5.3 Develop policy to dictate the application of audits to support continuous improvement.
- 5.4 Rewards only to be issued where employees perform beyond the call of duty, this needs to be driven to ensure fairness to all.
- 5.5 Benchmarking to be formalized and driven to investigate best practices (support from central AM function).
- 5.6 The effectiveness of corrective actions coming from PDRs to be investigated because of too many reds staying red on the BSCs.

- 5.7 To develop proper business case/expected return from improvement actions to enable prioritizing of improvement activities.
- 5.8 Implement a system (Business Process Management) to formally review all systems, policies and procedures on an annual basis, as part of the strategic process with formally dedicated responsibility (Team based ownership and review).
- 5.9 Implement process of root cause analysis and problem solving on the shop floor/frontline.
- 5.10 Six Sigma should be investigated, especially in the aquarium for the optimizing of processes.

## 6 PERFORMANCE MEASUREMENT

### Positive Points

- 6.1 Some asset management KPIs exist for management, identified as part of the Balanced Score Card initiative.
- 6.2 Performance standards (targets) have been set for measured KPIs.
- 6.3 Performance indicators are in most cases clearly indicated on all graphs and reports.
- 6.4 Some performance figures are available timely. (Monthly reports and also the implemented BSCs.)
- 6.5 The balanced score card dashboards is working well to introduce personnel to the use of graphical presentation and trending for measured KPIs.
- 6.6 Downtime reasons are recorded.
- 6.7 OEE is being measured.

### Opportunities

- 6.1 As part of the AM strategy, identify a comprehensive set of AM KPA's & KPIs relevant to each level of the organisation. Introduce these in the BSC. Refer to Central list of KPIs.
- 6.2 Introduce more equipment specific KPIs to monitor and react pro-actively on breakdowns and other failures. (MTTR, MTBF, Top 10, Reliability etc)
- 6.3 First investigate and develop correct KPA's before a lot of unnecessary KPIs are developed.
- 6.4 Introduce relevant asset effectiveness KPIs into the individual performance appraisals.
- 6.5 Display BSC with relevant KPIs in workshops. Graphs to be updated continuously and discussed frequently with artisans.

- 6.6 Don't display too many KPIs. Focus on the one's over which the individual has direct control.
- 6.7 Consider the use of photo reports in workshops and plant for walk-about inspections. Display these on notice boards.
- 6.8 Information on the effectiveness of action plans should be made public (how much time, money etc. were saved).
- 6.9 Use downtime information more actively to reduce repair time. Reasons for extended downtime can be measured and eliminated.
- 6.10 OEE should be driven as the no.1 measure on performance of the plant and cascaded to all levels where applicable; it should also lead to corrective actions. OEE can be measured for sub sections of the plant.
- 6.11 Some of the measures need to be replaced and formula for calculation reviewed.
- 6.12 Integrity of measures suspect in some cases, perform spot checks to audit validity.
- 6.13 Need exist for system that can display performance measures in real time and online (SAP).

## **7 SYSTEMS & INFORMATION**

### **Positive Points**

- 7.1 The GMS and GSS (Store) system is integrated, although this interface is not fully utilized.
- 7.2 EB system implemented that should be able to give easy access to technical manuals, drawings and catalogues.
- 7.4 Some equipment performance history is kept in the GMS.
- 7.5 Most operations (planning, scheduling, reporting) are computerized.
- 7.6 Plant configuration is reflected on the system, but only on a high level.

### **Opportunities**

- 7.1 The CMMS needs to be more user friendly, be able to perform component tracking.
- 7.2 The CMMS not to be used mostly as a time keeping tool for artisans but should be able to capture all maintenance operations and cancel the need for Excel spreadsheets.
- 7.3 Capture root causes for all failures and track costs on equipment level in central place (CMMS)
- 7.4 Ensure that all users of information systems (EB) have been properly trained to allow efficient utilization of the systems.
- 7.5 The CMMS should be fully integrateable with the other business information systems.
- 7.6 Management information should be easily extractable from all the systems by all users.(Provide necessary training)
- 7.7 A formal process needs to be developed to effect changes and updates in the system.
- 7.8 Analysis of management information to be supported by a process and tools to assist in effective decision-making.
- 7.9 Information that is entered into the systems to be scrutinized more rigorously to ensure the quality of information (e.g. from job cards).

- 7.10 There is a fair amount of complaints from workshops stating that the planning office doesn't update the GMS system and relevant preventative schedules.
- 7.11 Start now to develop full asset database and hierarchical structure of the plant in time for the SAP implementation down to level of "Bill of Materials".
- 7.12 Proper shutdown planning to be done on MS Project or similar software package.
- 7.13 Determine information requirement from different levels in organization and deliver.
- 7.14 Keep updating RAT-Maintain to enable planning of human resources in the CMMS until rest of SAP is implemented.
- 7.15 Investigate allocation of cost centre to equipment level to enable life cycle costing etc.
- 7.16 Is it viable to completely do away with a library for keeping hard copy drawings, catalogues and manuals?
- 7.17 Statistical analysis can be employed to determine the optimum operating point of an asset, investigate!



## **8 WORK MANAGEMENT**

### **Positive Points**

- 8.1 Call out procedure exists.
- 8.2 Random over inspections done by Charge-hand.
- 8.3 Maintenance supervisor gets a list of outstanding work.
- 8.4 Preventive maintenance activities are scheduled a week in advance.
- 8.5 Opportunistic maintenance sometimes performed.

### **Opportunities**

- 8.1 Review and implement effective work planning and control procedures for all types of work (include representation from all departments and levels).
- 8.2 Agree and document the roles & responsibilities wrt WP&C in order to lay down the rules very clearly. Roll this out to the job descriptions and individual KPIs as well as perform the necessary training.
- 8.3 A consolidated list of outstanding work (Backlog) must be generated on a weekly basis for all supervisors to enable proper prioritizing and resource planning. Clean up the current list of backlog urgently; some items more than 400 days overdue!
- 8.4 The current planning cycle to be increased from a weekly to at least a 3 weekly window to enable improved planning and scheduling of spares and special tools.
- 8.5 More effective use can be made of opportunistic maintenance and the planning department should coordinate it.
- 8.6 Always generate follow up work orders as specified on feedback of work orders and capture it as corrective maintenance if arising from scheduled inspections or walk-about.
- 8.7 Time estimates should be reviewed on a regular basis with the relevant disciplines and also compared to the actual report from the system.

- 8.8 Planned Task Observations and Over Inspections to be formalized and scheduled often, Requestor to also sign off job to indicate satisfaction. This should improve quality of maintenance.
- 8.9 Establish infrastructure to support Work Planning and Control processes e.g. Loading Boards etc.
- 8.10 Institutionalize and develop proper agenda for a combined Maintenance/Production planning meeting (based on the requirements for WP&C processes).
- 8.11 Planning department to act as quality gate for works orders.
- 8.12 Some workshops need to be supported more effectively from the planning department and their requirements taken into consideration.
- 8.13 Planning to be more involved in the resourcing for jobs.
- 8.14 Artisans should not be wasting time chasing spares, include staging of spares as part of work planning and control process.

## 9 MAINTENANCE TACTICS

### Positive Points

- 9.1 GMS PM activities are scheduled according to pre determined frequencies.
- 9.2 Some condition monitoring principles is applied.
- 9.3 Some personnel have been trained in RCM principles.

### Opportunities

- 9.1 Perform a proper criticality analysis to rate the criticality of equipment.
- 9.2 Review the classifications of Planned and Unplanned work.
- 9.3 A formal maintenance plan design and review process to be followed to optimize the current maintenance mix on equipment. Involve all stakeholders.
- 9.4 Formalize continuous improvement activities into work planning and control processes to also assist in optimizing maintenance tactics on equipment.
- 9.5 When reviewing tasks ensure that the task instructions are clear and descriptive with the necessary parameters included also determine the spares or special tools required to aid in planning.
- 9.6 Install visual fault finding diagrams at the point of use for all critical equipment to reduce repair times. (Operator also to be able to make use of basic ones)
- 9.7 Ensure that root causes of breakdowns is identified and eliminated permanently by, where applicable, adapting the maintenance plan accordingly.
- 9.8 Consider expanding the scope of condition monitoring to include and extend the application of vibration analysis, oil analysis, NDT and Thermography.
- 9.9 Continuously and according to a prioritized system, develop and apply operating and maintenance work instructions to support routine operating and PM.
- 9.10 Include risk factors when developing maintenance plans.
- 9.11 Correct operation of equipment need to be enforced and operators held accountable for safe and proper operation of equipment.

- 9.12 Proper use and completion of pre-use checklists on equipment need to be enforced.
- 9.13 Train and certify maintainers and operators against the relevant instructions and apply it actively.
- 9.14 Quick fixes to be discouraged and if they do occur needs to be formally tracked and followed up with permanent solution ASAP
- 9.15 Oil analysis results to be communicated to all the relevant personnel.

## **10 MATERIALS MANAGEMENT**

### **Positive Points**

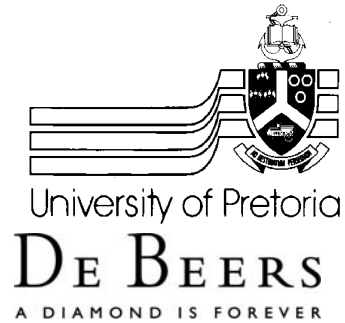
- 10.1 The central store is neat with clear bin locations. Sufficient storage area and racks exist to facilitate storage.
- 10.2 There is 24-hour access to the stores and stores deliver to the site.
- 10.3 Stock is replenished according to specified minimum and maximum stock levels (main stores only, no formal system in informal stores).
- 10.4 Stock accuracy is maintained through regular stock takes.
- 10.5 There is access to the stores information on the GSS system via terminals.
- 10.6 List of stock items and stock levels are reviewed (ABC analyses) and optimized regularly (only main stores).
- 10.7 An official spares supplier's list is kept for stock items to facilitate quick response time.
- 10.8 Good storage practices are applied with some informal maintenance activities applied (rotation of motor shafts, v-belts etc.).
- 10.9 Sub store in Aquarium well established.
- 10.10 GMS and GSS are linked, functionality available to automatically order spares for PMs.

### **Opportunities**

- 10.1 Review spares management procedure and improve spares forecasting from maintenance plans to enable optimum planning and staging of spares for maintenance activities.
- 10.2 Include spares acquisition and rotatable control processes, must address warranty control and quality assurance of new or repaired equipment.
- 10.3 Spares holding levels should be risk-based. Evaluate the use of a tool to assist in this and optimize.

- 10.4 Address inferior storage practices in informal stores - include stores in formal walk-about inspections.
- 10.5 Investigate stock-outs & delivery times on critical stock (As part of formal problem solving). These KPIs should be reported to the sections and included on BSC. Invite representation from stores on PDRs for levels 2 and 3.
- 10.6 Draw up a proper Service Level Agreement with stores.
- 10.7 All engineering spares should be controlled, not only the main store's stock items.
- 10.8 Review of stock items and holding levels to include all stakeholders.
- 10.9 Formal maintenance routines to be scheduled for critical spares where applicable and loaded into the CMMS (GMS).
- 10.10 Consider building sub-store in Red Area to allow quicker access to spares and materials.
- 10.11 Review critical spares for the Red Area and stock levels for these critical items.
- 10.12 Materials department to receive spares requirements forecast based on the maintenance plan.
- 10.13 Housekeeping in satellite stores need to be improved.
- 10.14 Big opportunity exists to establish alliances with suppliers, investigate.

## Appendix B: Survey Questionnaire



### MASTER’S DISSERTATION SURVEY QUESTIONNAIRE

DEPARTMENT OF ENGINEERING AND TECHNOLOGY MANAGEMENT

Details of person completing the questionnaire:

Full Names				Company	
Designation				Telephone	
Department				Email	
<b>Question:</b>	Please complete this survey questionnaire after reading the attached excerpt from a draft dissertation “ <i>Asset Management Auditing-the Roadmap to Asset Management Excellence</i> ” compiled by FJ Mollentze				
1. The definition for Asset Management as quoted in 2.1 of the	Agree fully	Partially Agree	Dis-agree	I don’t know	Comments:

article describes the concept of physical Asset Management clearly, considering the whole life cycle of assets.					
2. The elements of the developed framework, for Asset Management, address most of the possible elements/business processes within a typical organization as described in 2.2.	Agree fully	Partially Agree	Dis-agree	I don't know	Comments:
3. The Framework is simplistic and easy to understand (down to Supervisor level ).	Agree fully	Partially Agree	Dis-agree	I don't know	Comments:
4. The Asset Management Audit methodology described in 2.3 is practical and could easily be applied to your organization.	Agree fully	Partially Agree	Dis-agree	I don't know	Comments:



5. The application of the Asset Management Audit methodology should have the potential to positively affect the profitability or success of an organization.	Agree fully	Partially Agree	Dis-agree	I don't know	Comments:
<b>Additional comments:</b>					
<b>Signed:</b>			<b>Date:</b>		

Please return fax the completed questionnaire to (+267) 588 1243 attention FJ Mollentze or email to fmollentze@debswana.bw