The practical implementation of a sound Maintenance Management System

Jan Myburg

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Abstract

Successful implementation depends fully on a thorough understanding of how Physical Asset Management / Maintenance Management functions as an integrated system. Once this understanding has been obtained, it must be documented in such a way that it can be communicated, taught, and used as reference. Such a "Physical Asset Management Policy" then serves the purpose of giving direction to the implementation project, and it allows for all aspects of the full system to be supportive of each other.

This article attempts to give a broad outline of some aspects of Physical Asset Management, and subsequently touches on the implementation process.

The practical implementation of a sound Physical Asset Management System

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1. Objectives

To provide an **overview only** of a robust approach to implementing a Physical Asset Management System, with some emphasis on the most salient points.

Note that the very wide scope of the topic makes it impossible to investigate physical asset management down to any level of detail.

2. Summary of historical background

The concept of *Reliability Engineering* has its roots in the early 1950's, arguably accelerated by mass production and statistics. Although this discipline has been slow to find widespread recognition in South Africa, it has elsewhere been developing along two main lines: The physics of failure and the use of statistical techniques to understand failures better.

Since the 1960's, the concept of "Reliability Centered Maintenance" (RCM) was initiated by the "Federal Aviation Agency" in the US. An initial investigation was done to determine the feasibility of frequent, fixed frequency rebuilding of aircraft components. This investigation resulted in some surprising findings:

a. Regular, fixed frequency rebuilding of components had no significant effect on the aircraft's reliability; there were however some exceptions to the rule.

b. For a high percentage of the component types, a preventive maintenance (PM) approach cannot be applied successfully.

The idea is certainly not to make a "sweeping statement" that these findings are absolute and should be valid for all industry segments. In the author's opinion, these findings resulted in the awareness of the need for a "total approach" to maintenance – in other words, what the most appropriate mixture of maintenance types for a given equipment type, in a given operating environment, should be. This term *"most appropriate mixture of maintenance types"* is often called the "maintenance strategy".

It became apparent to both maintenance practitioners and industry leaders that the maintenance required, and the cost thereof, over the lifecycle of the asset, is largely a function of the design. Equipment is designed to perform a specified function at a specified rate, while maintenance is all about preserving the capability of the equipment to perform such function.

Therefore, some groundbreaking work done since the 1960's laid the foundation for the maintenance approach that took us into the twenty-first century – **approaching maintenance holistically, with a high dependence on systemization**.

Since the early 1970's there has been an increasing awareness that the traditional view of maintenance as a "necessary evil" is short-sighted and indeed limiting. A focus shift started to take place, from spending maintenance Rands on preventive, detective and corrective activities towards including "design for maintainability" in the maintenance thinking. This focus shift gave rise to the development of asset lifecycle models like **Terotechnology** (based on the Greek word *"terein" – to guard or look after)*, the **EUT (Eindhoven University of Technology)** model, the **Maintenance Cycles** model (Jasper L Coetzee) and many more. All of these positioned the business of maintenance as a sub-set of a more comprehensive "lifecycle economic management of assets" approach. This approach is the combination of management, financial, engineering, and other skills and practices applied to physical assets. The aim is lowest lifecycle cost.

Since the late 1980's a number of major maintenance-related disasters have speeded up the development of more formal, structured approaches to Maintenance Management.

Examples of such disasters are:

1. The Piper Alpha disaster (Cullen, 1990), which began with a routine maintenance procedure. The pressure safety valve of a back-up propane condensate pump needed to be checked, but the work couldn't be completed by the end of the shift. Permission was granted to leave the rest of the work till the next day.

   However, later in the evening the primary condensate pump failed, and the back-up pump was started. Gaseous product escaped at high pressure from the hole where the pressure relief valve should have been installed. The escaping gas ignited and exploded, blowing through the firewalls. Oil lines were destroyed, and large quantities of stored oil was ignited. The deluge system was not activated because it had been turned off.

   The gas risers from the other platforms became hot enough to weaken and burst. These were steel pipes of 24 to 36 inch diameter, containing flammable gas at 2000 pounds per square inch. This resulted in yet another jet of fuel which dramatically increased the size of the fire.

   Most of the 167 people who died suffocated in the accommodation areas.

2. The oil price crash (Saudi Arabia Economic Policy after the 1986 Oil Price Crash), which led to the Saudi Arabia governments' emphasis shift to improving the efficiency and maintenance of its public assets.

3. The Texas City Refinery event (Rigot, 2007), which highlighted a number of organizational shortcomings, including:

   - Work environment encouraged procedural noncompliance
   - Ineffective communications for shift change and hazardous operations (such as unit startup)
   - Malfunctioning instrumentation and alarms
   - Poorly designed computerized control system
   - Insufficient staffing
   - Lack of human fatigue-prevention strategy
   - Inadequate operator training for abnormal and startup conditions
   - Failure to establish effective safe operating limits.

The current state of the art is as follows:

1. Maintenance and its management are regarded as a sub-set of a larger system of "Physical Asset Management".

2. Various sub-systems of Physical Asset Management have matured and became well-entrenched, particularly Reliability-Centred Maintenance (RCM), Total Productive Maintenance (TPM) and Total Quality Management (TQM). TQM has its origins in a 1951 publication by Armand Feigenbaum, and has since developed into a comprehensive business management methodology which spans all organizational segments.

3. It is recognized that a single, standardized model will pull all the diverse ends of Physical Asset Management together. Much thinking has lately gone into this. The British Standards Institution (BSI) has just released the first major revision of its "PAS 55", a Publicly Available Standard aimed at the optimized management of physical assets. This PAS is available from the Southern African Maintenance Association (SAMA), and is a good "superior reference" for all maintenance practitioners and physical asset managers.

4. The holistic approach to maintenance and its management, which gave rise to the concepts of Physical Asset Management, relies heavily on well-designed, well-implemented and well-used information systems. This in turn forces standardization and the need to describe the business of Physical Asset Management clearly and exactly – systems analysts and software designers must be able to understand our needs.

Gartner (research paper G00130503, August 2005) predicts that “By year-end 2009, at least 60 percent of major organizations will have made cross-organizational business processes a main feature of their management structures (0.8 probability)”.

Some experts warn against “over-systemization” – although systemization brings optimization in various areas about, it can stifle innovation. Taking head of this warning simply means that systems must be developed to stimulate and invite innovation; certainly not that orderliness must be replaced by chaos. It is for this reason that all formal systems should be cyclical, with clear processes to take notice of non-conformances, ideas, improvement opportunities and the like.

3. Presenting the current state of the art as a system

3.1 An Overall View

To put Physical Asset Management into its correct slot within the broader business management environment, we must first consider the overall picture. The model shown below illustrates the salient elements of establishing and operating a business:

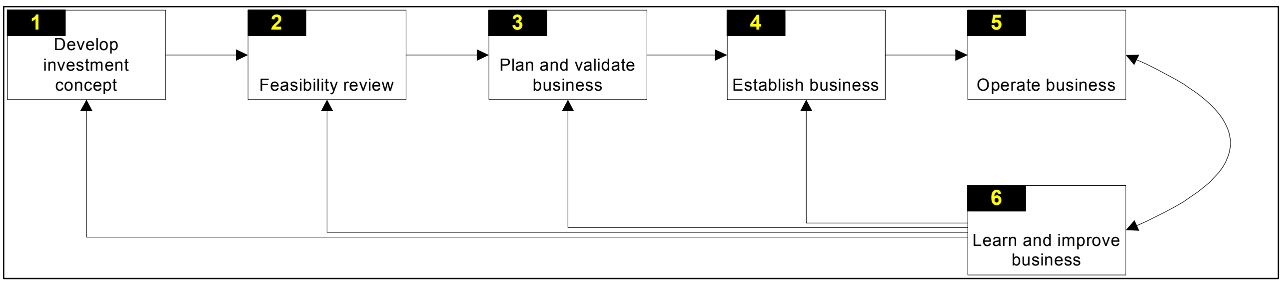

Diagram 1: Establishing and operating a business

The “Establishing and operating a business” model is not a sequence of activities which is executed once only – it is a cyclical model which means that all the activities shown are executed repetitively, for example at a fixed one year cycle, or at random as “induced by reality” like plant expansion, technology upgrade, new competitors entering the market, etc.

The elements, or more correctly sub-systems, are listed below. Note that the stratified nature of each of these sub-systems is taken into account, for example the equipment layer, the business processes layer, the information layer, and the organization layer:

1. Develop investment concept: The opportunity, the need, the product or service, and the technology alternatives are conceptualized. Alternatives are identified.
2. Feasibility review: The various aspects of establishing and operating the business are quantified, and commercially assessed. Risk and confidence is considered.
3. Plan and validate business: The final selection and confirmation of the technology alternative, design, final construction cost estimates, final operating cost estimates. Detailed designs are completed and verified.

4. Establish business: Construction, staff recruitment, training, systems establishment, creating the basic management structures.
5. Operate business: Producing, marketing and selling of product. In other words make a profit or provide the intended service at acceptable cost.
6. Learn, and improve business: Performance measurement in the traditional way, but also measuring performance of each individual business process or sub-system. Overall performance is simply determined by the performance of the individual business functions.

We can now look at Physical Asset Management from the perspective of this model.

3.2 A Physical Asset Management View

Let us start with the well-known elements of the "traditional" Physical Asset Lifecycle Model, and map them to the "Establishing and Operating a Business" model as depicted by diagram 1. In other words, we approach the traditional asset lifecycle with a business mindset; and the following very interesting points arise:

a) Acquisitioning: We purchase function and capacity, but we get with it a lifetime of maintenance requirements and the associated cost. This cost, together with the expected availability and reliability, will play a significant role in the success of our business venture for many years to come. Business feasibility studies cannot be done without an objective understanding of future availability, reliability, skills requirements, technology requirements, and software systems requirements. These in turn will have a profound effect on the organization structure, roles, ongoing training, and ongoing contracting of specialist service providers.

b) Installation and commissioning: Considerations like accessibility, special lifting and hoisting equipment, transportation etc need to be well-understood, as these bring about more cost, more maintenance, more administration, and more facilities. If we expect deterioration to start at the moment of start-up, we must have a clear understanding of the imminent maintenance requirements. In other words, commissioning the equipment without a formal, realistic maintenance strategy and the associated requirements is no longer a realistic option.

c) Operation: All the elements of the "total approach" come together during this stage in the asset lifecycle. The key questions here are:

    - Are we performing all maintenance tasks in a quality manner?
    - Are skill levels appropriate?
    - Are replacement parts available just in time?
    - Do our artisans have access to the required technical knowledge?
    - Are we continually learning, and using this knowledge to improve the maintenance strategies?
    - Do all of the above contribute to the expected / desired levels of availability and reliability, with a high level of predictability of cost?
    - Are we preserving the integrity and value of the asset base, thereby looking after the capital invested by the investors?

d) Replacement, disposal: The cycle starts anew, but we can be certain that technology has progressed substantially. The ever-shortening innovation cycles have a profound effect on skills required, training, engineering expertise and the availability of such expertise to artisans, possible outsourcing etc. The various technology directions therefore need to be reviewed.

3.3 Systemic Physical Asset Management

The question which almost certainly arises at this stage is “how do we now incorporate the various business considerations into a single coherent model that we can confidently apply in practice?”

Diagram 2 below provides an overview of such a “total approach” which puts the traditional cycle of acquisitioning, installation and commissioning, operation, replacement, and disposal within the context of a comprehensive Physical Asset Management System.

Only from this point onwards, shall we specifically refer to Reliability Centered Maintenance (RCM), as it is the opinion of the author that RCM, if applied correctly, has implications on just about every element of Physical Asset Management. The publication “Reliability Centered maintenance (second edition), 2001, John Moubray” is used throughout as reference, unless otherwise mentioned.

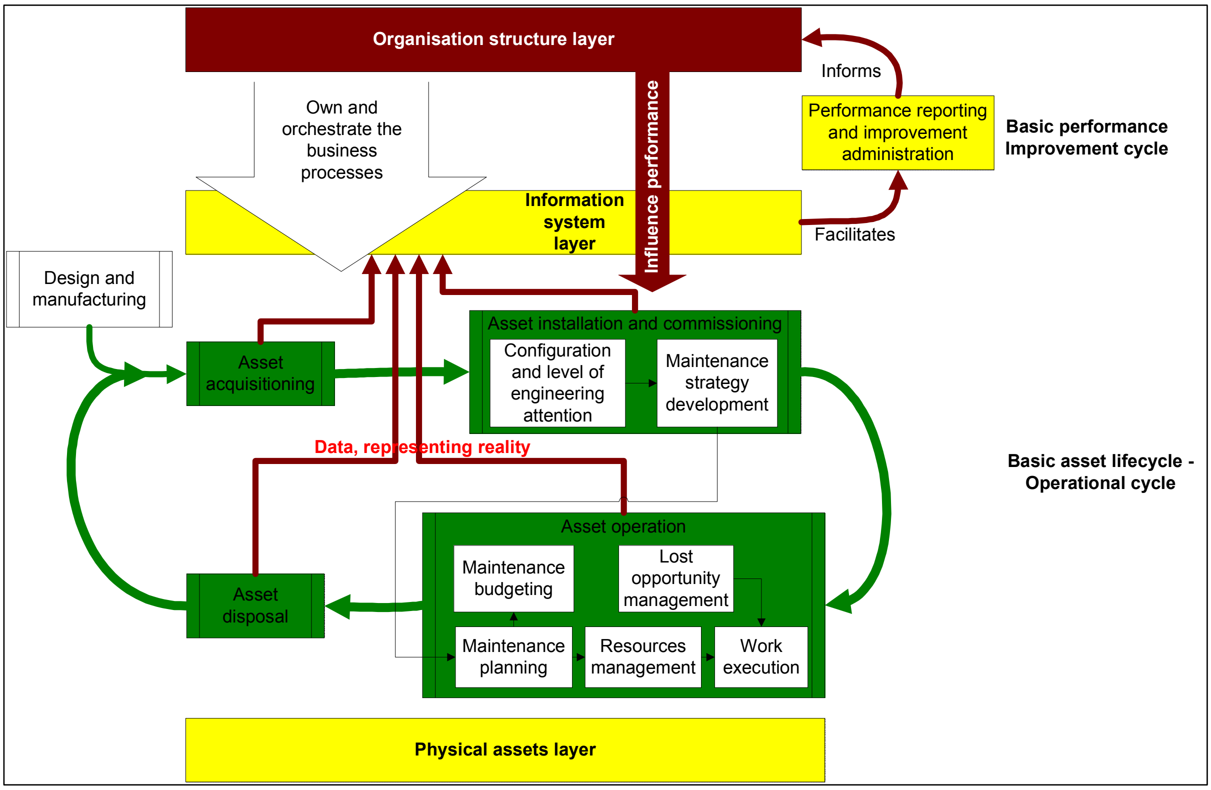

Diagram 2: Total Approach to Physical Asset Management

The elements shown in diagram 2 “Total approach to Physical Asset Management” are the following:

3.3.1 Physical Assets Layer

These are the objects of our management attention. The physical assets are taken up in a “Plant Register”. The fact that the Plant Register is not merely a “happening” but requires a thorough understanding of functional and hardware structures is best illustrated by the following questions which often arise in practice:

Point of contention	Asset Management view
Which items are to be included	Any item for which one or more of the following criteria are

in the plant register?	met: • It is of significance to production or service delivery. • It is of significance to the functions of supporting the production or service delivery. • It is owned or used by the organization. • There exist reasons why it should be tracked. • It is likely to require some kind of maintenance / engineering attention during its life.
What numbering convention should be used?	A lot has been written about this simple question, and there is arguably no absolutely right or wrong answer. The following points can be considered: • Keep numbers simple and short. • A number is essentially just an identifier, so do not include any meaning / intelligence / classification in it. Classification should without exception be done outside of the number. • There will always be differences between the financial and the maintenance view of what is equipment and what is not. An equipment item is often bought as a single, identifiable unit, and capitalized as such. Maintenance "level of focus" considerations will in all probability necessitate the identification and numbering of subordinate "assemblies", which cause all sorts of complexities when these items need to be taken up in the financial asset register as well.
Can equipment be a capitalized item in the financial asset register and at the same time is kept in the store for future replacement / swop-out purposes?	A good answer to this question is "Why not?" This is a good example of where real-life requirements prescribe systems / software functionality and configuration. For example, an item listed in the financial asset register cannot at the same time be kept in the stores' stock with a stock value – this immediately leads to incorrect financial (ledger) values.
To what level should the equipment be broken down for identification purposes (granularity)?	The key to this answer is to be found in Reliability Centered Maintenance textbooks. RCM is about preserving the capability of equipment to keep performing its production function. It follows that those items of plant which correlate with the lowest level primary production functions should be identified. These functions explain the reason why the equipment exists at all. This is the level which is the point of departure for an RCM study, and therefore it makes good sense to give a name to this "level in the functional / equipment breakdown structure where we find those items of plant that perform the lowest-level logical production functions". A possible name for the items sitting in this level is "Productive Equipment". Experienced RCM analysts will insist on "always starting the analysis at the top", which is then represented by this Productive Equipment level. The question which now arises is: "If I perform the RCM analysis at productive equipment level, and there sub- or lower

	level equipment items attached to the productive equipment, do I simply ignore them as equipment in its own right?" If such a sub- or lower level equipment does not fail by itself, or there is no need what so-ever for tracking or controlling of individual units, then there is certainly no need to identify these items as individual units other than items and sub-items on a parts list. However, if such a sub- or lower level equipment item is likely to fail by itself, then it implies that it has unique maintenance requirements in order to preserve it's capability to keep performing its intended function. In this case, the sub-equipment has no function in the primary production process by itself – it rather performs an enabling function which contributes to making the productive equipment work. The RCM analysis which is then performed on this sub-equipment will revolve around the specific enabling function. In summary then – multi-level equipment structures should be developed down to the level where individual items of sub-equipment, with specific maintenance requirements, have been identified. Caution should be exercised not to perform the RCM analysis at any level lower than is absolutely necessary, otherwise a whole series of difficulties begin to arise. More about this later.

3.3.2 Business processes layer

3.3.2.1 Design and manufacturing

The following citation from "Design for maintainability: The innovation process in long-term engineering projects", Ivory, Thwaites, Vaughan, 2001:

> *"A characterisation of the 'traditional' capital project would involve a customer, from its own resources, drawing up a detailed specification for equipment and commissioning a capital goods supplier to construct the facility under their or their agent's, supervision. The project would probably be financed on the customer's balance sheet. The equipment is then delivered to the customer and after a short period of warranty the supplier withdraws. What one UK minister referred to, with respect to the construction industry, as the BAD old days – 'Build And Disappear' (cited in Winch, 2000). It is the customer's responsibility to integrate the equipment with other physical or service features and to maintain and operate the equipment over its lifetime upgrading and replacing as necessary. The customer also remains responsible for the provision of the service to its own customers.*
>
> *Projects are now moving increasingly towards turn-key contracts – in which the end customer does none of the interfacing between the different parts of the system, but deals with a single supplier in the provision of the entire system (Maylor, 1999). The project will increasingly be financed off the customer's balance sheet requiring the finance house to take a greater interest in the performance of the project. Moreover, in many cases the customer now demands a service over a given period from the capital goods supplier (which may be subject to extension with or without the original supplier) articulated to reflect the service rather than the capital good (e.g. kilowatt hours, passenger miles, tonnes per hour). Contracts are negotiated to establish responsibilities, payments and penalties across the life of the contract, during which the supplier is encouraged to make suggestions as to the forms the equipment and services may take and how they will be delivered. The skills which the client has, in engineering terms, to comprehend what is being delivered, may be limited (Newcombe, 2000). Clearly, in this type of contract, demand has shifted from equipment supply-only with time limited responsibilities (i.e. a warranty period) to the supply of a package of goods and services over extended periods*

(e.g. rail franchise agreements). Thus, a capital goods supplier may now be responsible for the conceptual and detailed design of the project and equipment, its manufacture, assembly, installation, testing and setting to work. In addition it may be responsible for the maintenance and operation of the equipment, its service over an extended period and may even be responsible for dismantling and removing the project facilities at the end of their expected life.

Severe penalties in the form of liquidated damages are imposed by some clients for failure to deliver the agreed service level in compensation for lost availability. Historically, the owners of capital goods products have shouldered the burdens of high running costs and poor reliability, this burden is clearly now beginning to shift upstream to capital goods providers. Consequently, for capital goods firms, the main sources of revenue and risk have also moved from equipment supply to long term reliability and high standard service performance. In past capital goods projects the price of the equipment could approach 100% of the total project value.

In service led long-term capital goods projects the equipment can form as low as 10% of the total project value with the major revenue earning and risk sources concentrated down stream in service provision. Thus, it is a further critical feature of these projects that they serve a number of customers – not only the client who initiated the project (and its service users), but also the internal customers and users residing within the capital goods supplier, and associated consortia, who will depend upon the revenue stream once the project is up and running. Again, the finance house may be the contractual customer and will therefore make its own demands (e.g. for residual value).

Traditional capital goods projects are viewed as having a definite client in mind. From the client's perspective, the project is a purposeful undertaking stemming from the perceived needs of that client. In long-term projects, however, capital goods suppliers are delivering the product to themselves (i.e. they are their own customer) and the service to the traditional customer. This shift highlights the need to ensure low through-life costs rather than focusing only on first costs. As Winch (2000) has argued with respect to Private Finance Initiative (PFI) projects, innovation that will reduce running costs and / or increase reliability is essential to make projects affordable, and in these cases, to protect the consortia's revenue stream.

Thus, the key element in these emerging long term capital goods / service projects is to minimise overall project costs over the lifetime of an agreed contract. In this context, capital equipment costs can be seen as the flow of costs associated with the service provided by the equipment over time and not solely of the first cost of the equipment. One route to achieving an efficient, effective, low cost, profitable and desirable service is to explicitly incorporate maintainability and maintenance into the design of the service provision through equipment and service design. It is claimed that 60 to 75 percent of large equipment or systems lifecycle costs can be incurred through maintenance and support costs (Dhillon, 1999)."

From an RCM perspective, the statement "One route to achieving an efficient, effective, low cost, profitable and desirable service is to explicitly incorporate maintainability and maintenance into the design…" simply means that designers must be acutely aware of the inherent reliability / built-in capability of a specific design or configuration. The effect of various technology alternatives on the inherent reliability must be understood and considered, to the point where the contract vendor supplies production capacity together with clearly specified availability, reliability and cost.

3.3.2.2 Asset acquisitioning

Physical Assets are purchased to perform a specified function, meeting various standards. The fact that availability, reliability and operability could substantially impact future asset performance is often overlooked during the purchasing phase. The benefits of standardization, in particular the "intellectual and engineering knowledge" must not be under-estimated. The full impact of such standardization (or lack of it) will only become visible once the optimal maintenance strategy for the asset type in question is known, for example through applying RCM.

3.3.2.3 Configuration and level of engineering attention

RCM is about preserving the capability of a physical asset to perform its intended function at the specified level of performance. The only point of departure for an RCM study is therefore an exact understanding of the equipment's intended function together with the relevant performance standards.

The question "To what level should the equipment be broken down for identification purposes (granularity)" was raised under point 1 "Equipment layer" above. It is suggested under point 1 that the specific level in any sort of hardware breakdown structure, at which the RCM analysis should start, is where the equipment correlates with the lowest level logical production function. This level in the equipment structure is sometimes called "Productive Equipment Level".

The RCM analysis is now performed for a specific *configuration* rather than individual Productive Equipment Items. Productive Equipment Items of the type will be made up of exactly the same sub-systems, assemblies and parts. The Productive Equipment Items are technically identical. In other words, the RCM analysis is done by type of equipment in a given operating context, not for individual units.

If a Functional Failure is now something like "No pressure at outlet" and the Failure Mode is "Motor not turning", and there is a possibility that the motor can be involved with further Failure Modes, then the motor can be considered for an analysis in its own right. In other words, if a sub-equipment of the Productive Equipment is such that it performs a specific secondary or supporting function to the productive equipment, it is a contained unit with its own maintenance requirements, and / or it requires specialist skills and tools for maintenance, then number its function, identify the unit, associate it with the function, and perform the RCM study on it in that specific position (installed context).

This scenario starts touching on configuration control issues. Any configuration change like replacing the motor with a different make means that the maintenance strategy for the object now installed in that position is different to the maintenance strategy for the previously installed type of object. The RCM study must be repeated. Availability and reliability expectations might be different. The refurbishment work will have a different content from a scope, frequency, skills, parts, knowledge and tools requirements view.

3.3.2.4 Maintenance Strategy Development

This item forms the engine room of the RCM analysis. Let us start this section by looking at some definitions:

Defect

A defect is described as a situation where an item does not function properly, or does not function at all. The item in question here normally refers to production or services equipment, but also includes offices, buildings, supply and distribution infrastructure, roads, safety equipment, tools, special maintenance equipment etc.

The term "defect" has a meaning similar to that of the term "failure". When talking about failures, we normally distinguish between "potential failures" and "functional failures".

Functional failure (what / how is the equipment not working properly)

A functional failure is the inability of an asset to fulfil a function to an acceptable standard of performance.

Potential failure

A potential failure occurs when the item still performs satisfactorily, but we have reason to believe that some kind of deterioration is taking place which will in the near future result in functional failure. Functional failure is imminent.

Failure mode (mechanism of failure)

The failure mode describes what the mechanism of the functional failure is, like “Broken shaft”. This term is not to be confused with “cause”.

Failure root cause

The most fundamental cause / reason of the failure. We could regard something like “Suction pipe strainer blocked” to be the root cause, but further thinking and analysis could lead to something like “Used paper towels blown into bunting area, which then blocks the suction pipe”.

Because of the ongoing need to eliminate failure root causes, a “root cause code” is used for recording the reasons.

Maintenance strategy

A specification of the “types” of maintenance, which is to be done to specific equipment types, at a specific rate or frequency, under specific operating conditions. The diagram below provides a “structured breakdown” of maintenance into the various “strategy types”.

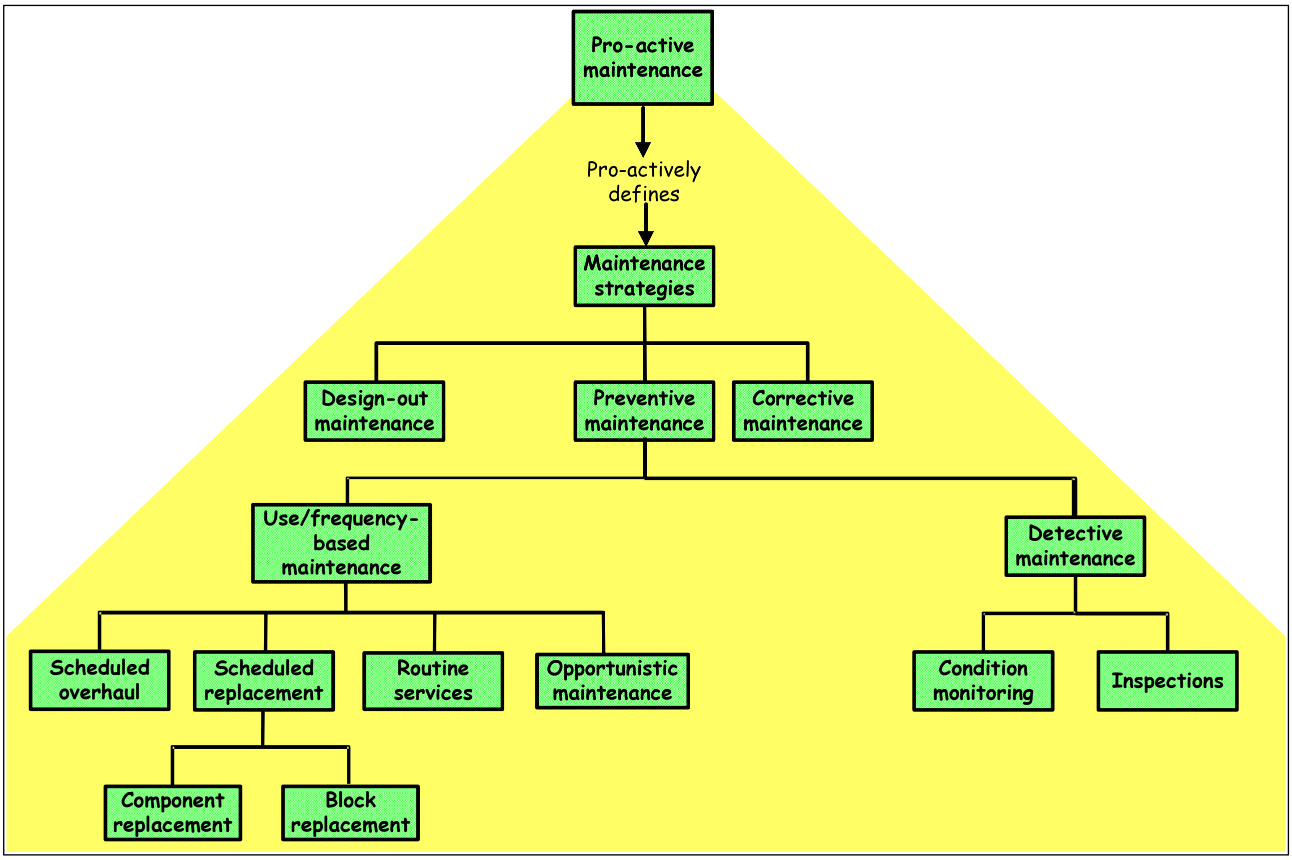

Diagram 3: Breakdown of maintenance strategies

Any combination of these strategies can apply in practice to equipment. And that is exactly what the process of “developing a maintenance strategy” is all about – to determine in an intelligent and sensible way what “types” of maintenance, and how often, is to be done to our equipment in order to best contribute towards the company’s sustainable profitability.

Reliability-centred Maintenance (RCM)

RCM is an internationally recognised methodology used to determine what must be done to ensure that any physical asset continues to perform its production function under specific operating conditions (in its present operating context).

Note that the SAE has approved a standard SAE JA1011 “Evaluation Criteria for Reliability-Centred Maintenance Processes”. This standard presents criteria against which a strategy-setting process may be compared in order to determine if such a process may be called an “RCM process”.

RCM entails asking seven questions in succession about selected (important) assets, as follows:

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

3.3.2.4.1 An approach to strategy-setting and continuous strategy improvement

The ideal situation is that the asset manufacturer supplies us with reliable, valid information on how to maintain the asset to best meet our production and cost objectives – also refer point 5.3.2.1 “Design and manufacturing”. But this is seldom the case in reality. In practice, few manufacturers are involved in the day-to-day operation of the equipment. After the end of the warranty period, manufacturers seldom get regular feedback from the equipment users about what fails and why. The best many of them can do is to try to draw conclusions about how their equipment is performing from a combination of anecdotal evidence and an analysis of spares sales. (Moubray, 1991).

It is thus clear that maintenance managers are to a very large extend dependant upon own in-house knowledge, the experience of other users of similar equipment, as well as a certain degree of experimentation to find the optimum maintenance “mix” for a given type of equipment under a given set of operating conditions. But that in itself poses a problem, because our assets are operated in a highly competitive marketplace, which leaves no room for experimentation. We are also witnessing an ever-increasing shortening of innovation cycles, which in turn has a shortening effect on the useful life of some specific-purpose equipment items. There is just no longer time or money to allow a good technician to build an intimate understanding of the sounds, smells and temperatures of an equipment item. In many cases, the complex nature and extreme utilization of the assets, together with staff turnover, will not allow this.

The answer to this very complex problem is to be found in three related areas:

- Developing a proper maintenance strategy through the disciplined use of RCM, whereby the knowledge vested in our technical staff is sifted, ordered and moulded into a formal maintenance strategy.
- A fast but thorough analysis of each defect as it occurs, with a view to continually increase the MTBF.
- A continual re-assessment of this maintenance strategy in the light of both the reliability and failure behaviour of the assets.

These three areas are illustrated by means of **diagram 4** on the next page:

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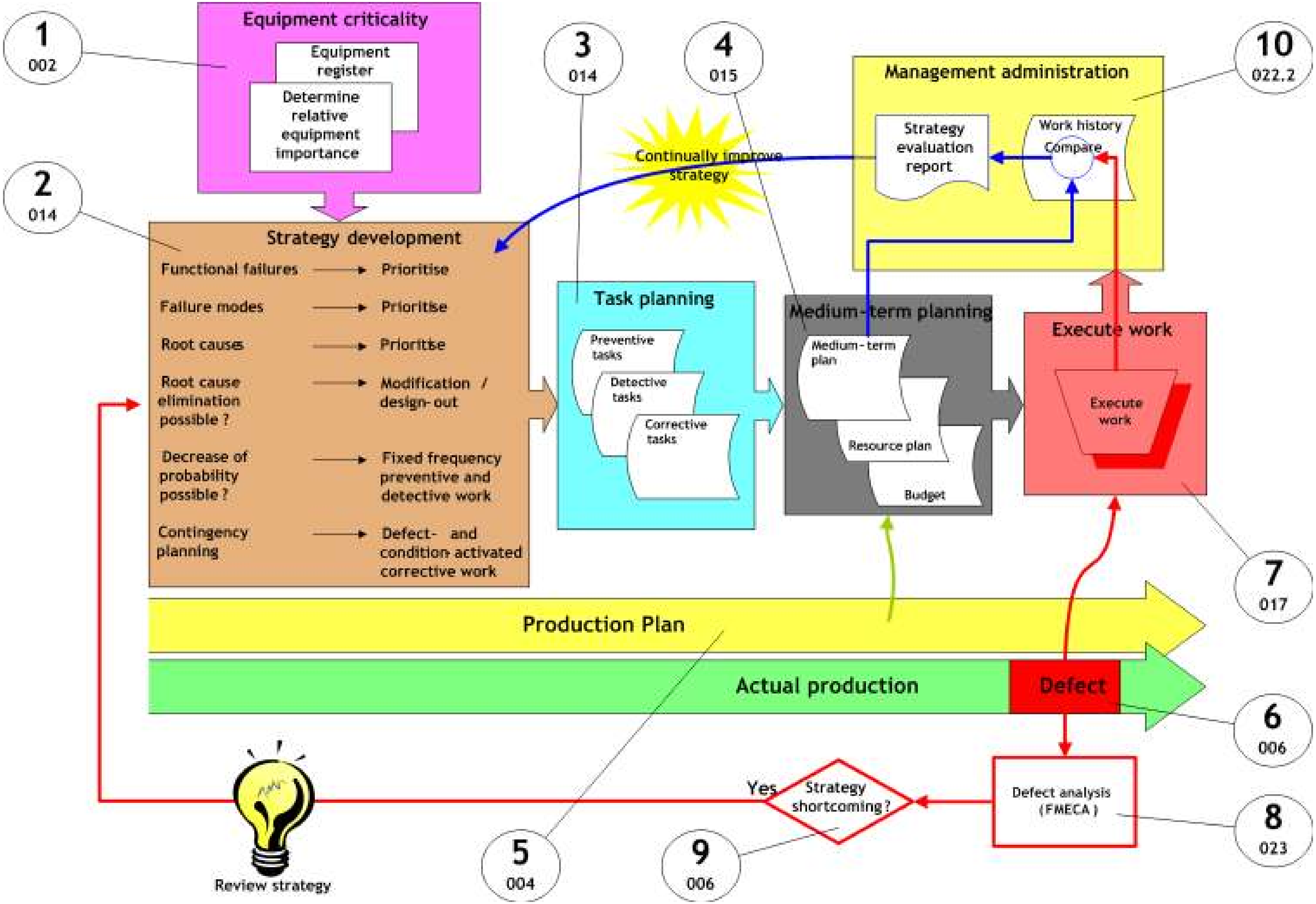

Diagram 4: Strategy-setting and improvement system

3.3.2.4.2 Developing the maintenance strategy

The first round of maintenance strategy development can be seen as developing a "going-in position strategy". The result of each step is stored in the information system to allow proper re-evaluation as the knowledge about the equipment's failure behaviour increases. The end result of this front-end analysis is a set (mix) of maintenance tasks, some of which are frequency-activated, some are condition-activated, and some are defect-activated. The micro (task) planning for these tasks is done, and a long-term schedule is generated.

Because we are no longer limited by expensive electronic storage and processing capacity, this version of the long term plan is stored away as our "master long term plan". This could eventually form the basis of a "zero-based" budget.

3.3.2.4.3 Defect investigation

As defects occur, it now becomes a function of our information system to compare if the actual rate of occurrence is in line with our original estimate. If not, a special instruction is to be printed on the repair jobcard to request a thorough investigation of the defect cause while the repair work is being done. The result of such an investigation could reveal that some of our initial assumptions were wrong, which should then lead to an immediate review of the maintenance strategy. If the defect was caused by other (exceptional) circumstances, no immediate review of the maintenance strategy might be required.

Each maintenance strategy review will lead to a rework of the master medium-term plan. These versions of the plan are then stored away with incremented version numbers. This, together with the "actual" asset history, will allow for sensible assessment of the impact of every strategy improvement.

The technique known as FMECA (failure mode, effect and criticality analysis) is used for defect analysis.

3.3.2.4.4 Continuous re-assessment and improvement of the maintenance strategy

The medium-term schedule contains the "expected result" of the strategy-setting process. It is thus easy to compare "actual results" to the medium-term schedule. This comparison is done in the form of the "Strategy evaluation report", and compares the execution rates of preventive-, corrective- and condition-measurement jobs to the schedule. Variances are identified, and such variances prompt the reliability engineer to investigate and improve the maintenance strategy.

More about this later.

3.3.2.4.5 The relationship between potential failures, functional failures and strategy improvement

The relationship between potential failures, functional failures and strategy improvement is illustrated by the "conceptual" P-F curve shown below:

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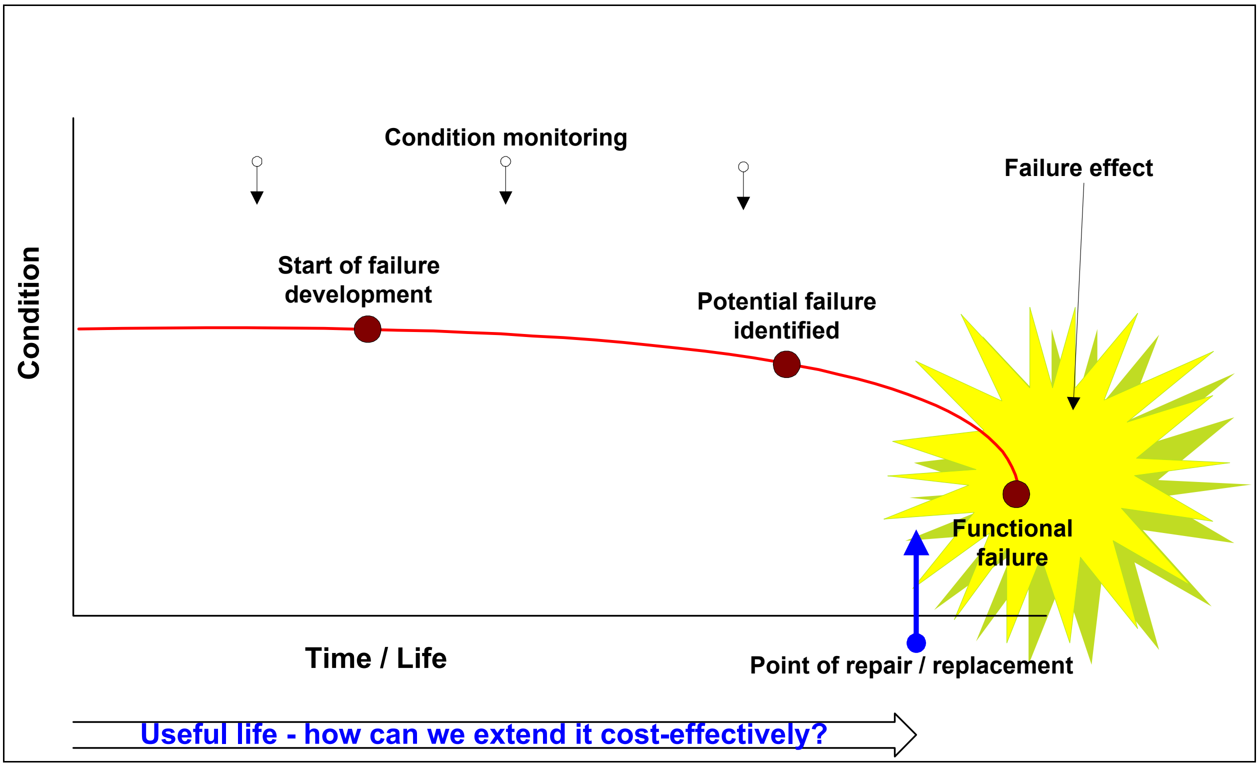

Diagram 5: The conceptual P-F curve

The point "Start of failure development" shown in the diagram above is often not a specific, identifiable point in the lifecycle of the item involved, but rather a gradual degradation of the condition / physical properties of the item.

Similarly, the point "Potential failure identified" does not necessarily mean that a sudden measurable degradation took place which is of such magnitude that it can be measured / observed. This point should rather be seen as the point where we develop a good enough understanding of the degradation of the item to start predicting the point of functional failure accurately.

From a maintenance improvement perspective, the Reliability Engineer should consider two possibilities:

- When the potential failure is identified, what steps can be taken to "postpone" the point of functional failure for this specific equipment item? Possibilities could be more careful operation (nursing the equipment), using special lubricants / oil additives, slackening transmission belt / chain tension to decrease lateral stresses, etc.
- What can we alter / improve in our maintenance strategy to generally extend the useful life for this type of equipment – for example changing PM job frequencies, changing PM job contents in terms of what is done, material and parts specifications etc, doing additional PM jobs, upgrading the quality of the repair / reconditioning jobs, specifying more stringent "acceptance criteria" in cases of contracted-out maintenance etc.

The P-F curve can be misleading, because it implies that equipment has a characteristic life, which ends at point F (functional failure). This is of course not true – much has been said about typical life. The approach is therefore to increase the "average value" of MTBF.

3.3.2.5 Maintenance Planning

The end result of the Maintenance Strategy Development is a mixture of preventive, detective and corrective tasks, with now and again an adaptive (design-out, modification) task. The preventive and detective tasks are each associated with a fixed frequency, while the corrective tasks are associated with an expected rate of occurrence. The adaptive tasks are associated with discreet dates.

For purposes of maintenance management, planning is taking place at three levels.

- Task planning: The output of the strategy development process is packaged as "standard tasks", optimized in terms of contents and resource requirements.
- Medium- to long-term planning: The maintenance tasks are projected into the future, at the hand of the allocated frequencies or expected rates of occurrence. Because the tasks are individually planned, and the resource requirements are known, an accurate forecast of labour, material, tools, workshop facilities, outwork etc can be made.
- Workshop planning: The compelling need to cut cost means that no skill hours are redundant – on the contrary, we mostly have more work in hand than can be done by the available staff. It is therefore critical from a production / service delivery perspective to allocate work to staff and machining workstations in a sequence that will maximize equipment availability. The well-known and often misused technique of work prioritization plays a major role here.

Based on the frequency, a medium-term maintenance plan is generated. In cases where production is subject to seasonal fluctuations, task frequencies will typically be expressed in terms of an output or "work done" unit. The future planned execution dates of the tasks are therefore converted from the production plan and actual to date production. The requirement is for the maintenance plan to be accurate and reliable, so that full adherence to the plan can be enforced.

Each task included in the maintenance plan should be associated with the attribute "Level of shutdown required doing the work". This attribute is used to identify future shutdowns at the hand of the medium-term plan, rather that simply accepting that "this is how it has been done for the past 20 years".

Diagram 6 below provides a simple visual representation of the medium-term plan:

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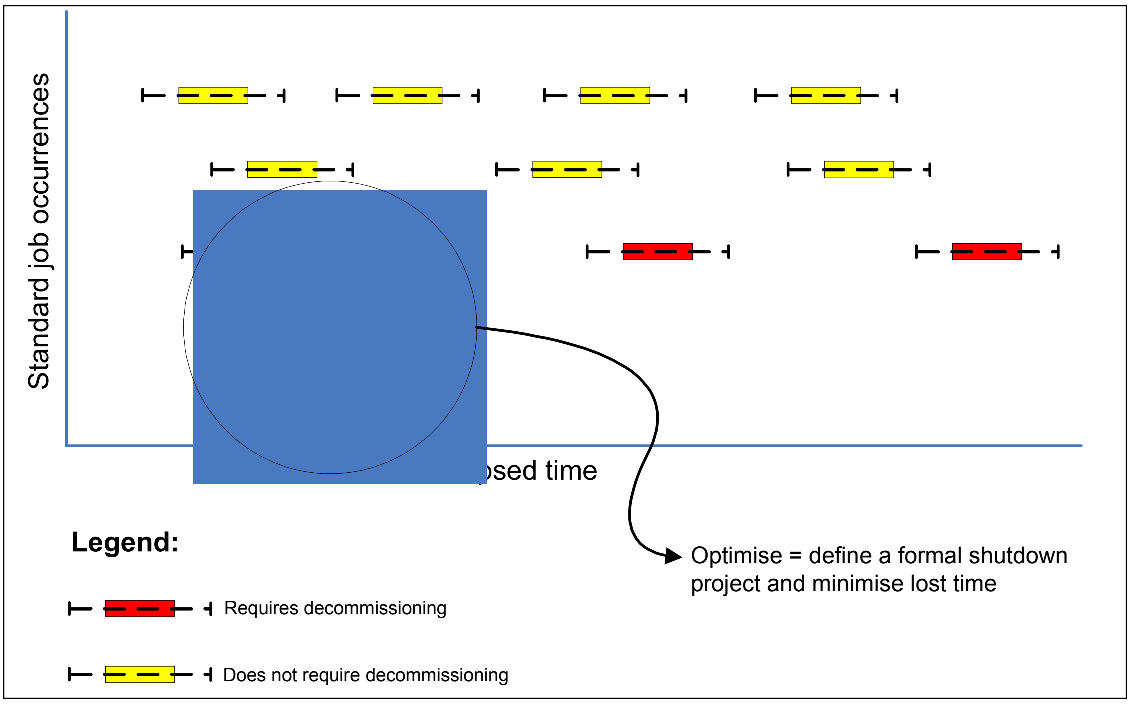

Diagram 6: Result of medium-term planning

The sample plan shown by diagram 6 illustrates that task frequencies, instead of being absolute, can be associated with a "frequency tolerance", which is an indication of the tolerance of the equipment involved towards adjustments of the planned task execution dates. The frequency tolerance as aid to identifying individual work packages that can be combined and optimized **without losing their unique identity** is obvious. If we also add a demand / **production forecast graph** to the medium-term plan, our confidence level in the planned shutdown dates are even higher.

Diagram 6 also suggests a more structured approach to shutdown project planning and control – instead of a big conglomerate of activities as we often find in practice, the project can be planned at two or more levels:

- Firstly, the work package level, where each individual job is a micro project in its own right, with critical path and resource profile.
- Secondly, the global project level, where each work package is represented as an activity.

This approach allows for the proper resetting of cumulative and condition "meters" for the individual jobs, individual job history without the work "disappearing" in the shutdown conglomerate, and therefore proper re-scheduling handling / calculation of the next occurrence date. The ongoing maintenance strategy improvement cycle is therefore not compromised in any way.

If we look at the medium-term plan over a longer period of time, we could find the following type of shutdown visibility:

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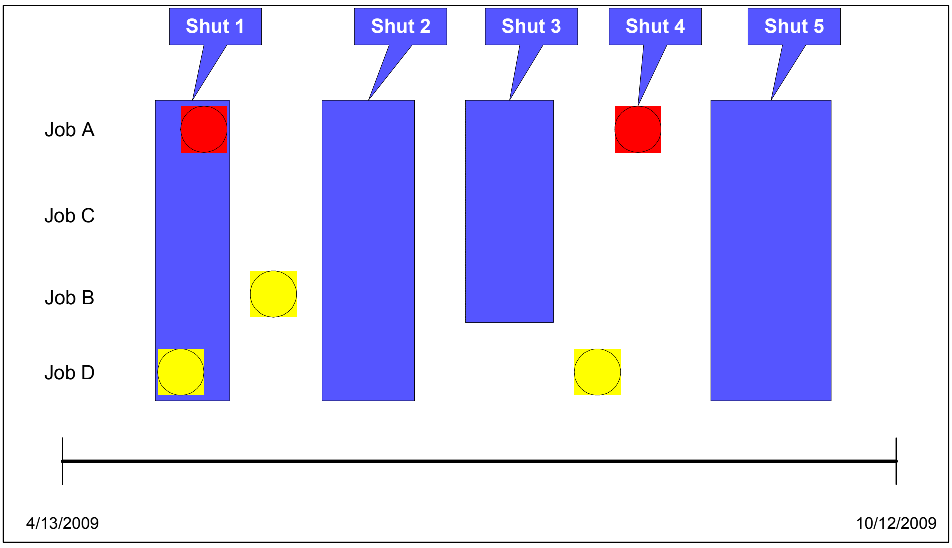

Diagram 7: Future shutdown identification

We can therefore conclude this section by summarizing that:

1. If a maintenance strategy is developed at the hand of a formal RCM methodology, the end result is a mixture of preventive, detective, corrective and adaptive tasks.
2. Some of the tasks mentioned above can be done while the equipment is in full operation. Some will require partial or extensive decommissioning.
3. A sound medium-term maintenance plan therefore provides a firm basis for determining future shutdown dates, and the (justifiable) scope of these shutdowns.

3.3.2.6 Maintenance Budgeting

The maintenance plan is calculated and compiled at the hand of "the right tasks", to be done to "the right equipment", at "the right frequency". Because the individual tasks are properly planned, the expected cost can be calculated quite accurately. The maintenance plan simply projects the individual tasks at the hand of the production plan. Therefore, the maintenance budget is essentially simply the financial requirements resulting from specific maintenance tasks planned to be done at specific dates in future, fine-tuned according to planned output.

3.3.2.7 Resources Management

The resources requirements are extracted from the medium-term plan in exactly the same way as the maintenance budget. Because the individual tasks are properly planned, the associated resources are known fairly accurately. This leads to confident contract negotiations with resource vendors, reduced penalties, and even the capability to arrange for technical and maintenance-related training at the most appropriate times.

3.3.2.8 Lost Opportunity Management

It is still common that organizations use the terms "Fault reporting" or "Defect registration". The idea of arranging, executing and managing business functions as cyclical, repetitive processes as mentioned in point 5.1 recognises the occurrence of a functional failure as generally undesirable, but also as an opportunity to understand more about the maintenance requirements of the equipment in question.

The initial RCM analysis is therefore in a sense extended by reviewing every functional failure critically, and feeding details like failure mode, effect and cause back into the maintenance strategy. This provides the minimum benefit of verifying that specific elements of the strategy is still valid, and the possible further benefit of improving the maintenance strategy by fine-tuning contents and / or frequencies.

3.3.2.9 Work execution

The two aspects of maintenance management that can arguably be regarded as the cornerstones of providing availability and reliability are:

1. The existence of a sound maintenance strategy as discussed,
2. But then also proper control over maintenance work execution.

The time and effort spent on RCM studies can in totality be undone by maintenance work that does not meet quality standards. The RCM study group or analyst typically assumes that the integrity of the equipment being analysed remains constant indefinitely. If that is not the case, and there is a tendency for the equipment to become increasingly unreliable, it simply means that any given maintenance strategy becomes invalid after a period. It is difficult if not impossible to determine what the duration of "validity of any given strategy" is, but it is certainly true that the strategy will remain valid and applicable if the equipment is maintained such that a certain level of integrity is maintained.

3.3.2.10 Asset Disposal

The useful life of the equipment ends.

3.3.3 Information System Layer

The information system "layer" in the stratified representation as shown by diagram 2 serves the purpose of summarising and presenting actual performance to staff. Note the use of the word "staff" instead of "managers". Time constraints and the scope of this paper do not allow us to delve too deeply into the business of reporting, but we need to make some key points:

1. If physical asset management is treated and managed as a sequence of inter-dependant business functions, then the performance of a given function depends fully on the output of its predecessors. Low quality parts for example will result in sub-standard equipment performance and / or life expectancy. A vague job description / position charter for any position will result in poor performance of the employee. Un-numbered equipment will lead to an inaccurate equipment register, etc.
2. The above point implies that the notion of measuring the performance of individuals might in fact totally defeat the object. Rather measure the performance of the individual business functions, assess the extent to which requirements are met, and then make corrections and adjustments.
3. If the stratified nature of physical asset management is fully investigated, the following logical "groups" of performance measurement comes to light:
    a. **Individual function performance**: Every single function, or in some cases grouping of functions with a common output is assessed at the hand of a small number (at least one) performance indicator.
    b. **Maintenance work**: A maintenance job which has been successfully completed,
        - conforms to specified quality standards.
        - can be expected to result in reliable equipment functioning for a reasonable period.
        - did not lead to any resource wastage.
        - was used as an opportunity to identify better ways of doing the job, as well as an opportunity to learn more about the "failure behaviour" of the asset.

    No maintenance environment can be managed if it is not known beyond any doubt that maintenance work done conform to acceptable standards.

c. **Maintenance strategies**: The maintenance strategy is the single most important element of the maintenance systems environment. It defines the types of maintenance to be done to specific equipment types, under specific operating conditions. In other words, the maintenance strategy tells us what maintenance work need to be done to which equipment items, how often.

   If we do not have full confidence in the applicability of our maintenance strategy, any amount of management effort spent on aspects like RCFA, work execution management etc will deliver only partial success.

   Also, the strategy needs to be continually reviewed and refined as operating conditions, equipment usage patterns, technology etc change.

d. **Maintenance resources**: The "categories" of resources are skills, parts / materials / consumables, tools and maintenance equipment, workshop facilities, external service providers, and production capacity. The totality of our maintenance "operating" cost goes into paying for resources. We therefore need to ensure the following:

   - That the right skill / quality resources are available at the right time.
   - That we don't pay good money to keep unnecessary resources on board.
   - That the required resources will be available when maintenance work is to be performed.
   - That, if we need to add a contingency allowance to the resource availability, this contingency allowance will be in line with the risk level.

e. **Production capacity**: Assets are purchased in the first instance to provide production or service capacity. We therefore need to know at any point in time that:

   - Capital invested in assets is in line with production / service demand.
   - We got maximum operability (fitness for purpose) for each Rand invested in assets.
   - The time period during which the asset will reliably perform its function will be such that we will get maximum return on our investment.

   Once our assets are in operation, we need to ensure that:

   - Utilisation of the assets is to their full potential.
   - Failure behaviour of the assets does not interfere with the production process, or result in production- or service-related losses.

f. **Maintenance organization**: As previously discussed, we can only manage our physical asset environment successfully if we have a sound understanding of the basic business processes. These processes have to be both done or executed, and managed. This leads to the concepts of responsibility (the person or team doing the processes) and accountability (the person ultimately managing the processes).

   Therefore, it is a firm requirement for a well-managed organisation to clearly allocate responsibility and accountability to business processes. This allocation needs to be continually reviewed and optimised in terms of scope of "work" involved in each process, and staff capacity to do the "work".

   In addition, we know that any individual's attitude towards his / her work and company has a profound effect on his / her productivity. It is therefore also required to have an understanding of the levels of motivation of the staff, as well as the factors contributing to low / high levels of motivation.

g. **Investment integrity**: The ultimate objective is to provide the level and quality of service as specified in the Metrorail vision / mission statements. This is done at a cost, which is partly determined by how well the assets are cared for. The set of measures under this category makes the "result" of the total management effort visible from a service delivery and return-on-investment perspective.
h. **Safety**: Safety management is all-encompassing. All business activities take place within a total environment of safety awareness.

3.3.4 Organisation layer

The idea of an integrated system, with a high level of element inter-dependency, implies that the organization structure should be designed very specifically to promote proper functioning of the individual functions, but also proper functioning of the total system. This statement brings us right into the debate around centralized versus decentralized maintenance organizations.

During the last ten years or so, most plants defined operations as the maintenance customer, and gave production unit managers more control of the resources – the typical decentralized maintenance organization. The initial result was a surge in equipment operability, as plant / operations managers directed resources towards equipment problems that had been chronically interfering with output and continuity. The craftsmen dedicated to the units felt needed and as if they were making a more direct contribution than before, as part of a central pool. They learned their unit's equipment intimately, and became more proficient and committed to unit performance.

What could possibly be wrong with that scenario?

The following is quoted from *"Emerging concerns and limitations (The central issue: How to make distributed maintenance work – S Bradley Peterson)":*

"In speaking with maintenance and operating leaders in dozens of plants in this past year, we have heard a number of repeated concerns:

- There is no consistency to how units are performing maintenance.
- In most cases the dedicated crews are working on schedule breakers because of the ease of deploying them. If there is a plant-wide priority system, it has no application to these crews. Rather, work is done to the same urgency as the production schedule.
- Planners dedicated to units do very little routine planning. Instead they are expediters, on-call supervisors, and when they do plan, it is for outages.
- Maintenance craft skills are deteriorating. No one in the organization is assuring the continuing development of craft skills.
- The CMMS data quality is highly compromised. Some units may use the CMMS, and others don't.
- The remaining central force feels alienated from the unit-based maintenance crew.
- The Reliability Engineering Team (usually those who perform the predictive maintenance function) are frustrated that their success is limited to those units whose managers understand their value.
- Important measures of planned maintenance, such as *% planned work*; *schedule conformance* and *% PPM* are declining or very stubborn at improving. Operating units have no standard definitions of these measures, and may or may not even measure and record them".

Christer Idhammar's experience is as follows:

*"If your basic maintenance practices (Planning & Scheduling, Preventive Maintenance, Stores, Technical Data Base) are not **instituted as a way of life**, do not make this move! Why? It will lead to having many poorly performing maintenance organizations instead of having one poorly performing maintenance organization. On top of that you will expect several, often inexperienced, maintenance managers to implement and / or improve on these maintenance basics. Because of lack of knowledge in maintenance management, time, interest, willingness or all of the just mentioned the following things are very likely to happen within six to nine months:*

- *More maintenance people on shift. Because it feels more secure that way. As one consequence of more maintenance people on shift, operators will request a lot of "Honey Do" jobs.*
- *More maintenance people will be stationed in areas to be available and ready to react to problems. Because this leads to faster repairs of problems.*
- *Work requests will not be entered into the computer system, because it is easier and more convenient to just call people.*
- *It will become more difficult to move people between departments for shutdowns.*
- *Overtime and contractor hours will start increasing even though there are more people on shift.*
- *Backlog will start to go up.*
- *Equipment reliability starts declining. At this point the total maintenance cost has gone up, but operations managers might not see the whole picture."*

The above is a valid statement of departmental boundaries – each "section" of the maintenance function is encapsulated by a plant- or production section. But departmental boundaries are not limited to the level one or plant-dedicated maintenance crews – it includes functions like configuration management, drawing offices, project offices, purchasing, stock control etc.

This brings us to the key question: "Should our concern be about breaking down departmental boundaries in our current organizations, or have we progressed far enough towards a holistic physical asset management model to take a fresh look at organization structures and roles?"

The author is of the opinion that a smooth migration from a traditional maintenance organisation to a state-of-the-art physical asset management organisation is not possible. The reason for such opinion is mainly that a very specific set of skills and a very specific organisation structure become apparent when roles are defined and aligned with a "physical asset management" rather than a "maintenance management" mindset.

It follows that an in-depth understanding of "physical asset management" is required in order to design a physical asset management organisation.

Breaking down departmental boundaries – in other words, effectively transforming a system is not possible without **profound knowledge** of four main areas (Deming):

- Appreciation for a system, which has to do with the system boundaries; its intended goals; the system's inputs, processes and outputs; and how we are doing towards reaching the goals.
- Knowledge about variation.
- Psychology of individuals, the broader society, cultures and changes.
- A relevant knowledge base.

4. Practical implementation guidelines

4.1 Introduction

PAS 55-2 provides guidelines for the application of PAS 55-1. The diagram below, taken from PAS 55-2, shows the dimensions of Physical Asset Management. The display of "Organizational commitment and culture" right in the centre is of particular relevance – each and every dimension of the PAM system is either subject to, or fully dependant on the organizational aspects. This underlines some aspects of implementation that we will discuss in more detail later, namely

- Demonstrated management support.
- Full commitment to the project.
- Roles in the implementation project must be clear. Clear responsibility, accountability and performance standards must exist.
- The simple question of "what do we implement" is critical. We must have a profuse understanding (refer Deming) of the micro-constituents of the system, as well as their inter-dependencies.

Diagram 8: The dimensions of successful asset management – PAS 55-2.

4.2 Point of departure

The implementation of a sound maintenance management system is essentially moving from "where we are right now" to a more desirable position. This simply indicates that there are six main phases to any implementation project:

1. Define the desired state. We need to understand exactly what the more desirable position, or expected end-result, of the implementation project is.
2. Assess the current state. We need to understand exactly what our current position is within the reference framework of the desired state.
3. Describe the journey from the current state to the desired end-result.
4. Execute the implementation plan.
5. Stabilize and entrench.

6. Actively and enthusiastically orchestrate ongoing, incremental improvement.

4.2.1 Define the desired state

Why would we consider the implementation of a sound maintenance management system? Simply because we know or have a strong suspicion that we can improve asset availability, reliability, safety and cost. It is nothing more than an investment, which we expect to generate a meaningful return.

A proven recipe is to document the desired state in the form a "Physical Asset Management Policy", which takes PAS 55-1 as point of departure or superior reference.

The objectives of the Physical Asset Management Policy is typically something like the following:

> To provide a framework and minimum requirements for managing the total "Company X" Physical Asset Base. This framework serves the purposes of:
>
> 1. Defining a "desired state" of Physical Asset Management, and will therefore guide all Business Units towards achieving excellence. This policy will therefore eventually lead to a high level of standardization.
> 2. Defining the minimum rules which govern how we should manage our physical asset base.
> 3. Specifying specific aspects of Physical Asset Management which are centralized in order to reap the benefits of a single point of control.
> 4. Binding together all lower-level procedures and work practices to form a single, optimized systems environment.
> 5. Providing a common language and reference framework to facilitate clear and to-the-point performance assessment, communication, and training.
>
> The ultimate objective is therefore to enable focused and structured development of the "Company X" Physical Asset Management Environment in order to support the production and operations functions with optimal levels of equipment availability, reliability and operability, while preserving the integrity of the asset base, leading to maximum Return On Investment (ROI) over the short-, medium- and long term. This will be done safely and with due respect for the environment.

Because the Physical Asset Management Policy will serve as direction-giving guideline for all aspects of the system, quality time and broad-based inputs and participation is essential. The integrity and acceptance of this document must be such that every single employee will protect, promote and defend it at all cost. A fatal mistake which is often made is to inherit an existing policy from some other company, or even to pay a number of consultants to develop it on behalf of the company.

The key point is that if a company wants to implement a sound maintenance management policy, they must have a thorough understanding of the nature, components and dependencies of such a system. The Physical Asset Management Policy is the most important step towards such understanding. A substantial amount of resources and money will be spent towards reaching the desired state, and a clear understanding of this desired state is arguably the single most important risk mitigation factor.

4.2.2 Assess the current state

Assessment in this context means that we have to make an objective comparison between our current Physical Asset Management System and the desired state, with the desired state being the yardstick. It is worthwhile getting an independent authority, with no embedded marketing agenda, to perform an audit of the current state and compare it to the desired state, as defined by the Physical Asset Management Policy; for example the Southern African Maintenance Association (SAMA).

It is sometimes argued that one should not dwell on the current situation too much, and rather get on with the implementation of the new system. This argument is invalid. Experience teaches that there are four to five definite “steps” in the improvement of the PAM system. A single jump from zero to hero is not possible. Rather, a well-planned improvement from “level current” to “level next”, taking particularly weak and strong points into consideration, should be executed. (Also refer *The Theory of Constraints (Dr. Eliyahu M. Goldratt. The Goal, 1984*).

In other words, a sound understanding of the current state, compared to the framework of the desired state, will help to allocate resources and skills where needed, achieve quick wins, and work towards a climate of confidence.

A typical “Maintenance maturity growth diagram”, sometimes called “levels of excellence in maintenance” is shown below:

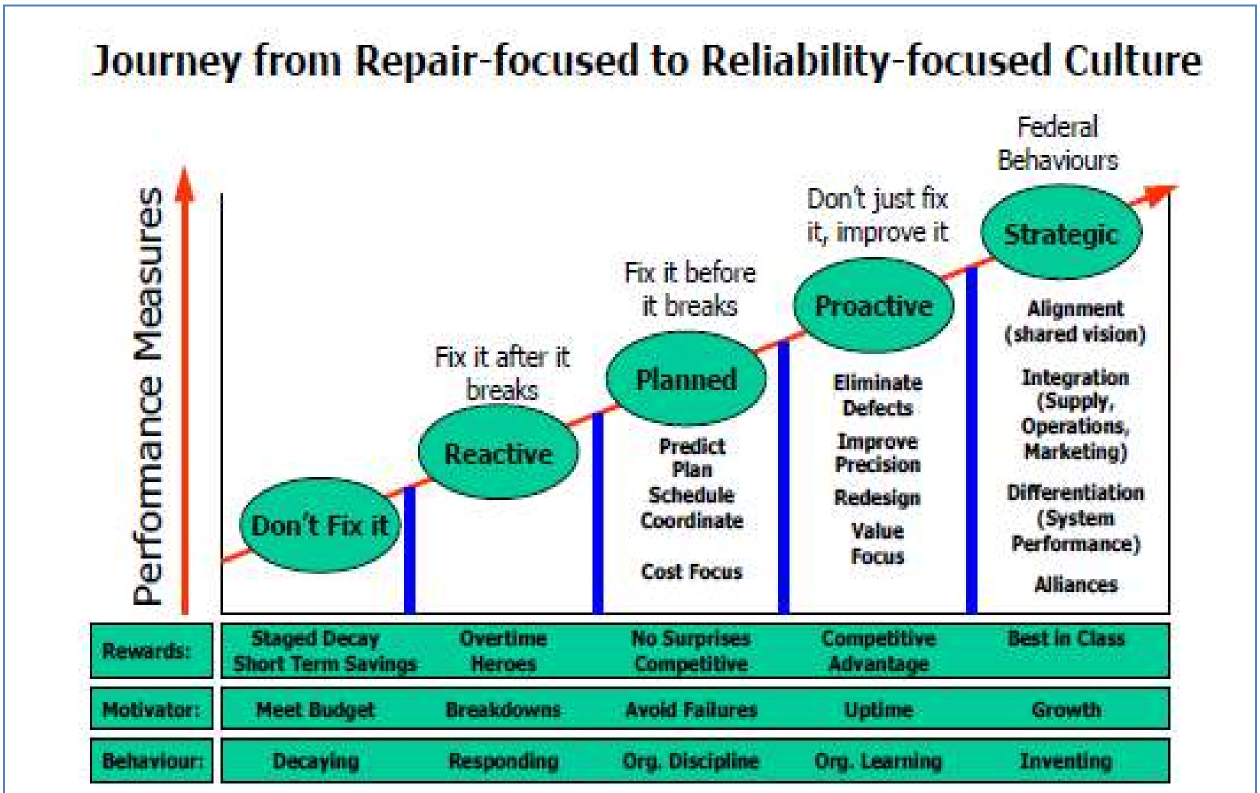

Diagram 9: The journey from a Repair-focused to a Reliability-focused culture

(Recognition John Woodhouse)

The current state assessment should address the following layers of the stratified PAM system:

1. Physical asset system: The extent to which intended function is satisfied, general integrity, overall condition.
2. Physical asset management system: A function-by-function comparison of the real-life situation to the desired state.

3. Organisation layer: The extent to which roles are aligned with functions, as well as the suitability of background, training and experience. Functions that are centralized / not need special attention.
4. Information layer: The extent to which standard management reporting reflect the performance of specific functions or groupings of related functions.
5. Vision and mission of the business: The extent to which the PAM system is aligned with shareholder expectations.

4.2.3 Describe the journey from the current state to the desired state

It has been experienced in practice that the implementation of a physical asset management system often does not yield the expected results. The main reason for this phenomenon is simply that the implementation team often overlooks the "operational impact" of the new system. In laymen's terms – a successfully installed system is only a very small fraction of a successfully operated system. Proper integration with business processes is required, as well as intensive end-user training. But equally important is the overall 'manage-ability" of the systems environment. The information (system) is a resource just like staff, money etc. But it is a "complicated" resource – it must therefore be implemented with discipline and orderliness.

The best way to get a clear understanding of how to arrive at the desired state, is to employ a two-phase implementation approach:

4.2.3.1 Phase1: Mobilization and planning

The first priority of every implementation is to define the specific scope and plan of action. Due to the size/scale of most implementations and the number of different organizations and specialties involved, the first phase is referred to as 'Mobilization and Planning' with a scope document often called a "Mobilization Plan". The Mobilization Plan is developed for all implementation efforts, both where the implementation is large and complex, impacting many or all of a company's business units, and where it is smaller, impacting only one facility or business unit. The Mobilization Plan addresses the key issues regarding organization, resources and schedule. It provides an initial view of any potential obstacles to a successful implementation and forms the basis for preparing the detailed Implementation Plan and key topical plans.

The Mobilization Plan describes the scope of and provides estimates and schedules for the several 'special' plans and surveys needed as background for development of the Implementation Plan which represents the 'final' scope and plan. A key element of the Mobilization Plan is the 'preliminary' estimate and schedule for the entire implementation which is refined and 'firmed up' in the Implementation Plan.

Therefore, the Mobilization Plan contains rough-cut estimates for the entire project, but is essentially a detailed plan for arriving at the final, objective Implementation Plan.

Two key aspects of this implementation methodology are that:

1) It promotes the completion of several planning and survey steps BEFORE significant implementation activity and spending begins,
2) It produces detailed work plans for the various teams so that the implementation is both efficient and cost effective.

This approach is strongly recommended over the more common approach of 'charging into implementation' before enough is known about the scope, resources, budgets, schedules, constraints, conflicts, omissions, etc.

Clearly, the Mobilisation Plan will address that milestone on the journey to the desired state which will bring the organization to the next level of excellence – refer diagram 9: "The journey from a Repair-focused to a Reliability-focused culture.

4.2.3.2 Phase 2: Final implementation plan

The real implementation plan is now compiled at the hand of the result of the execution of the Mobilization Plan.

4.2.4 Execute the implementation plan

A number of sophisticated and proven implementation and change management approaches are used, so for purposes of this article we shall only focus on a few of the high-risk areas.

First and foremost, it is never a good idea to contract a third-party service provider to manage the project. This means that you abdicate before you even started. Instead of utilizing a unique opportunity to expand your in-house knowledge pool, entrench communication and management structures, and really start an ongoing process of continual improvement, a situation of passing the buck, blame-shifting and cover-your-backside is created.

A second important point is not to see the implementation as a single, isolated project. Rather treat it as if it is the starting point of a whole new dispensation – it is building a foundation and mechanisms for ongoing improvement. All advisory and management structures created during the project keep on functioning after the project.

Thirdly: It happens sometimes, especially where the project has a large I.T. component, that project ownership is seen as residing with the I.T. function. This is similar to the first scenario mentioned above, and in reality even worse. You do not want to:

1. Be forced to sign off a document which states that "the 1400 standard reports in the system all represent international best practice, therefore meet my requirements as user".
2. End up with procedures and standards in a foreign format.
3. Have endless problems because classification schemes, codes and numbers were designed to suit the design of a particular software product, not the realities of monkey wrenches, dust and grease.
4. Be held up in your improvement efforts because of some in-efficient and irrelevant "change committee" which tries to be clever.

The fourth important point is to adhere to your defined "desired state" at all cost. If your organization has been characterized by crisis management and fire-fighting, chances are that you will tend to create more crisis situations, even if simply for the reason that your staff are used to it, and feel uncomfortable in an organized, orderly situation. Do not get sidetracked.

A last point, and arguably the most important point when it comes to implementation, is communication, participation and training. Your project plan and project definition report must make ample provision for these aspects. You cannot have too much of it. These aspects go together with visible management support, and as said earlier, the implementation project should be seen as the starting point for an ongoing process of orchestrated improvement. It is therefore advisable to re-look at existing committee- and communication structures, and upgrade these to include project-related matters – not only during the implementation, but for many years to come.

4.2.5 Stabilize and entrench

Your Physical Asset / Maintenance Management System has been implemented, so now you can relax and watch how equipment availability and reliability starts improving. Wrong!!

The essence of an implementation project is:

1. To develop a better understanding of the environment / system you are operating and managing.
2. To put mechanisms in place to capture more timely, representative and accurate data.
3. To create an environment which is such that artisans will do quality work.

4. To present the data in understandable form for purposes of making better forecasts of maintenance and resource requirements.
5. To develop and entrench the disciplines required to ensure that all of the above are done according to the requirements of the system definition.

The responsibilities of the maintenance manager therefore become more challenging after the implementation project. At least one additional dimension is added to his / her management portfolio, namely that of systems management. The responsibilities pertaining to ongoing systems management obviously need to be formally defined, and must be added to the various role descriptions.

Depending on the size and geographic spread of your organization, it might even be necessary to consider additional, specialist roles to take care of some aspects of systems management.

In conclusion of this paragraph: Many organizations make the mistake to regard the implementation of a Physical Asset Management / Maintenance System as a once-off project which comes to an end when the last activity on the implementation plan has been completed. Instead, the approach should be that the end of the formal project forms the start of a “new maintenance management dispensation”. For the new system to succeed, role descriptions must thoroughly provide for the additional / new responsibilities to make the system work and grow.

4.2.6 Actively and enthusiastically orchestrate ongoing, incremental improvement.

Let us first consider a possible organizational arrangement that favours system-related improvement. The diagram below shows a sub-set of a possible Physical Asset Management organization which is aligned with the natural logic of Physical Asset Management:

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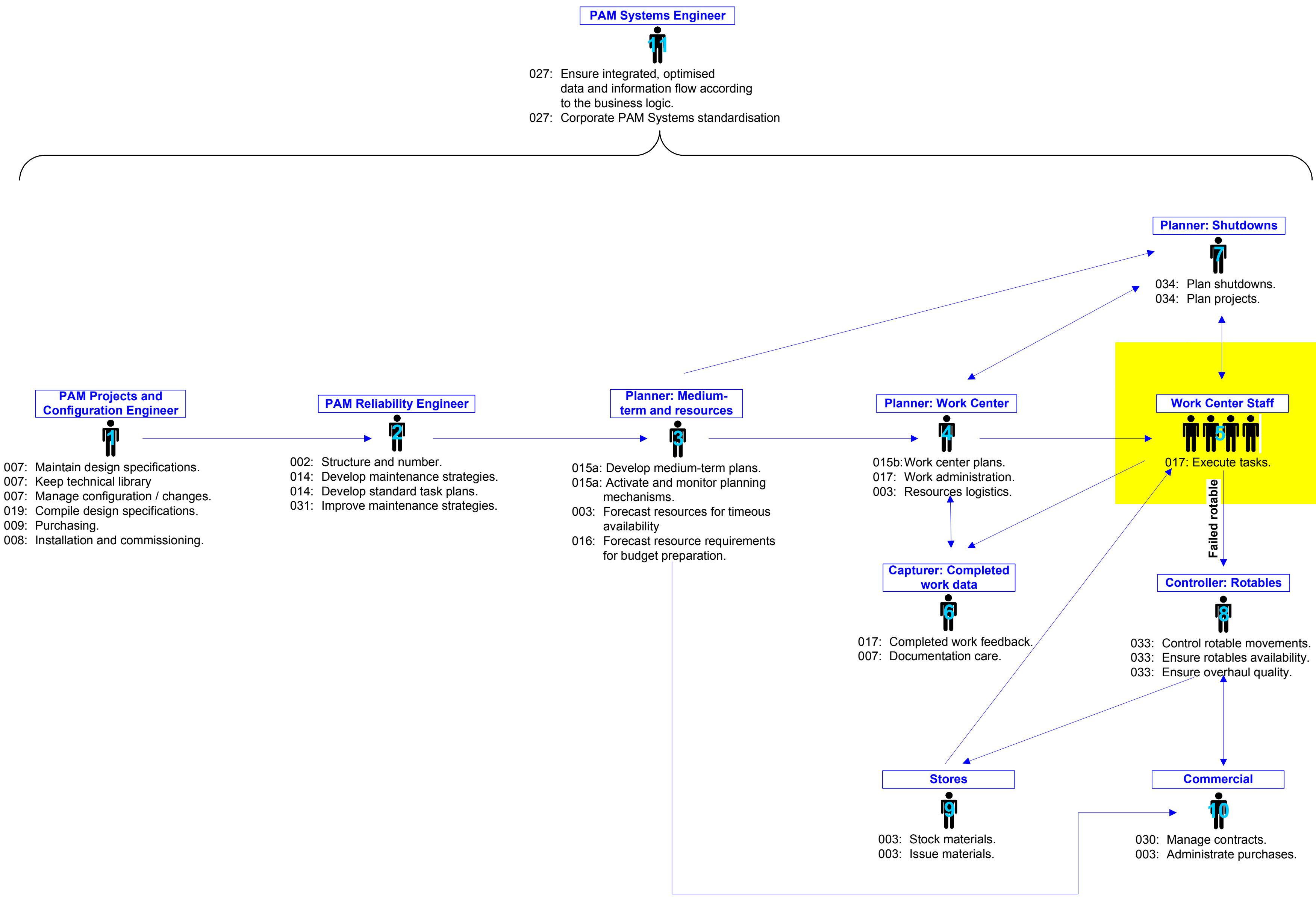

Diagram 10: Function-aligned organization (partial)

The discussion below refers to the numbers shown in the diagram:

1. PAM Projects and Configuration Engineer: An accurate equipment register exists. Documentation fully reflects the real-life configuration of the equipment. All technical documentation is indexed and stored such that it is easily accessible to all functionaries, including artisans.
2. PAM Reliability Engineer: A formal plan for the ongoing development of formal maintenance strategies exist. This plan takes the relative importance of individual equipment items into account. Each functional failure is thoroughly investigated with a view to improve the formal maintenance strategy, and is eventually cross-referenced to the change made to the strategy. All maintenance tasks are pre-defined as standard tasks.
3. Planner: Medium-term and resources: Based on the pre-defined maintenance tasks, a medium-term maintenance plan (at least one year planning horizon) is maintained. This plan is used as basis for the development and ongoing refinement of resource forecasts, as well as the “financial implications” or maintenance budget.
4. Planner: Work center: A detailed work execution plan (one week planning horizon) is maintained, in close liaison with supervisors and production staff. Unplanned tasks (tasks which have not been pre-planned, standard tasks do not exist) are regarded as highly undesirable. All required resources are known and have been confirmed prior to work execution.
5. Work center staff: Staff are motivated and highly skilled. Skill levels are constantly honed, and there is an acute awareness of task quality standards.
6. Planner: Shutdowns: Major work, which could be a collection of smaller individual tasks, is managed at the hand of a practical project plan. The critical path is known, and the effect of extended duration on production output has been considered.
7. Controller: Rotables: The pro’s and cons of in-situ repair versus item swop-out have been considered, and functional- and hardware breakdown structures were developed accordingly. Spare rotables have been obtained and put into stock to achieve the best balance between capital outlay and lost production.

The second point to consider is the “drivers of improvement”. The Physical Asset Management Policy discussed earlier should clearly specify which key performance indicators should be regarded as minimum to give a representative indication of how the Physical Asset Management System is doing.

The diagram below provides an overview of the highest-level performance measurement areas, once again mapped to the natural logic of the business of Physical Asset Management:

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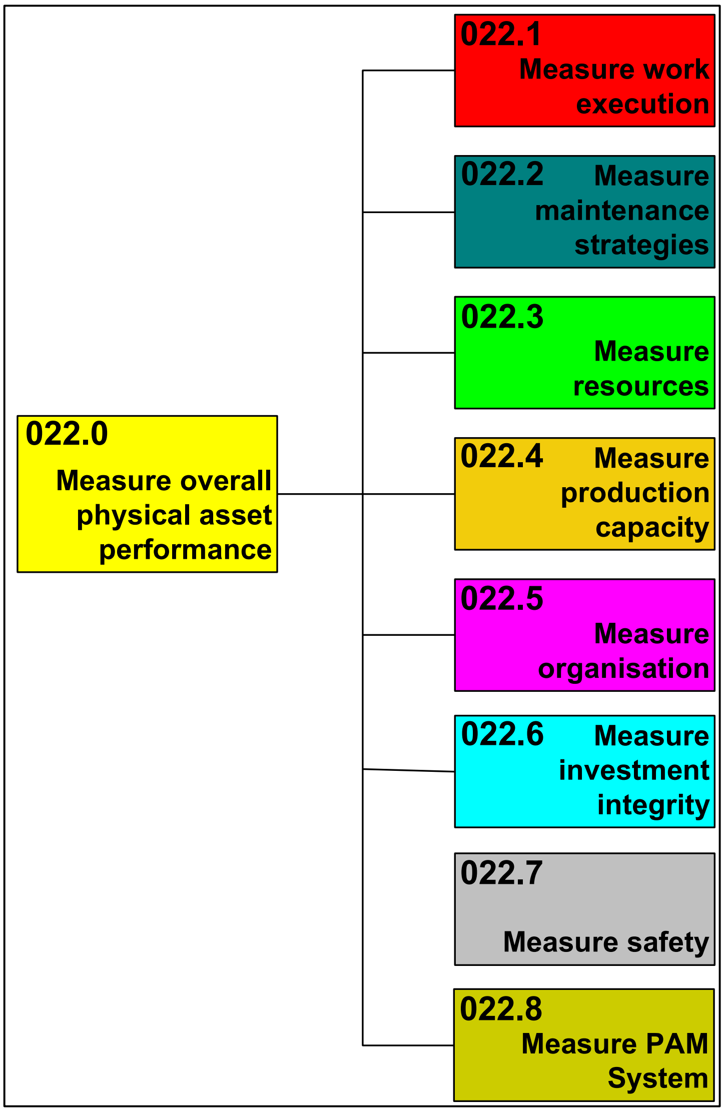

Diagram 11: High level performance reporting areas

The various performance reporting areas in diagram 11 are self-explanatory, and are therefore not discussed in more detail here.

It is however important to observe that these reporting areas are summarized from the "lowest level". This means that for each and every simplistic function which is a building block of the total PAM system, a desired standard of performance should be defined. By setting improvement targets for these lowest level functions, the process of ongoing improvement can be actively managed. Note that it is the opinion of the author that high-level improvement targets (for example "To improve equipment availability from 90 % to 95 %") is totally useless, unless it has been cascaded right down to work execution level. For example, the target to improve equipment availability could practically mean

- To shorten the duration of service C to equipment type X by 20 minutes.
- To replace the worm gear in speed reducer B when wear at area D exceeds 0.07 mm.

In other words – do not add to the increase of the well-known "maintenance strategy gap" – maintenance results are determined at the shop-floor, and not in the boardroom.

5. Conclusions

A deep understanding of how the business of Physical Asset Management hangs together should always be the starting point of any improvement initiative. Improvement is brought about by people who share the same vision and have a true desire to improve. A common understanding of “where we are going” is therefore essential. But beware of becoming “flavor-of-the-day chasers” – thoroughly complete and stabilize each improvement action before moving on to the next one.

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