Chapter 2 – Understanding Equipment from a Management Perspective

2.1 Introduction

In order to effectively address the dilemma of the maintenance manager (as discussed in Chapter 1) it is important that all parties involved in the production cycle understands the value added by effective maintenance. It needs to be further explained that the value added by effective maintenance is not as visible as the functions performed by the operational team, as maintenance management focuses on loss elimination and the prevention of losses and potential losses. From an overall management perspective both the operational and maintenance teams need to understand what their equipment is capable of delivering, where the bottle necks in the process lies and what the losses are. By clarifying these issues one can set the path for changing the perception of maintenance being a cost function.

2.2 Assessment of equipment capability.

2.2.1 Equipment capability

Katila, (2000) describes capability as the ability of equipment to perform the functions required of it, for the period that the functions are required this is mainly made up of:

- the equipment's original design (capacity, strength & endurance limits, etc.);
- the degree to which the equipment may have been modified;
- the equipment's current condition, and;
- the production (functional & schedule) requirements.

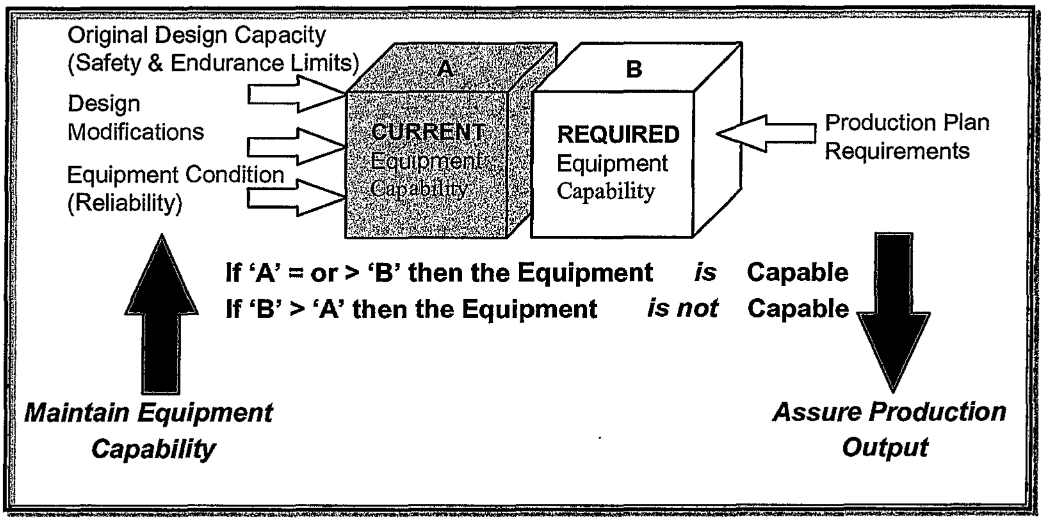

Figure 2.1 – Measuring if equipment is capable.

From the above it can be seen that if equipment is not capable typical actions for correction / improvement could either include:

- reduce the production requirement (difficult if the business is selling high volume quality product), or;
- assure the equipment condition through effective maintenance.

If the equipment is still not capable, then it must either be replaced, or its design capacity be increased through engineering modification.

Capability does not only apply to equipment alone, but also to:

- people (e.g.: have the right motivations, skills & knowledge, making the right decisions, and working to the required standards of quality and timeliness), and;
- management systems and procedures (e.g.: providing the correct information, checks and validations, etc.).

2.2.2 *Knowing the equipment's capability*

Equipment Capability determines the success of business from a financial point of view mainly due to the following:

- the original capability costs money - this is the capital cost of design, purchase, construct, install, and commission, etc.;
- maintaining the capability costs money - this is the cost of maintenance, and;
- the capability directly governs production output which in turn influences the revenue one can earn from sales.

It is important to balance equipment capability with business requirements because:

- If equipment capability is too low then production requirements cannot be met. This could influence the customers' requirements for delivery of quality products to required schedule, resulting in the loss of market to competitors.
- If equipment capability is too high then excessive capital is tied up. This could mean that one will not be able to meet shareholders requirements for a competitive return on capital, resulting in the loss of funding to more attractive investments.

2.2.3 *Measuring equipment capability*

To gain a simple understanding of equipment capability, it is necessary to only look at *the actual production rate achieved over a period.* This is what the equipment produces, given the way it is currently operated and maintained. When looking at these results, it is often found that the full potential of the equipment capability is not realised.

2.2.4 Loss factors in equipment capability

The potential that could be achieved from the *equipment capability* can be determined by comparing the *"As Is"* and *"Should Be"* situations (Katila, 2000). This is more comprehensively illustrated by Figure 2.2.

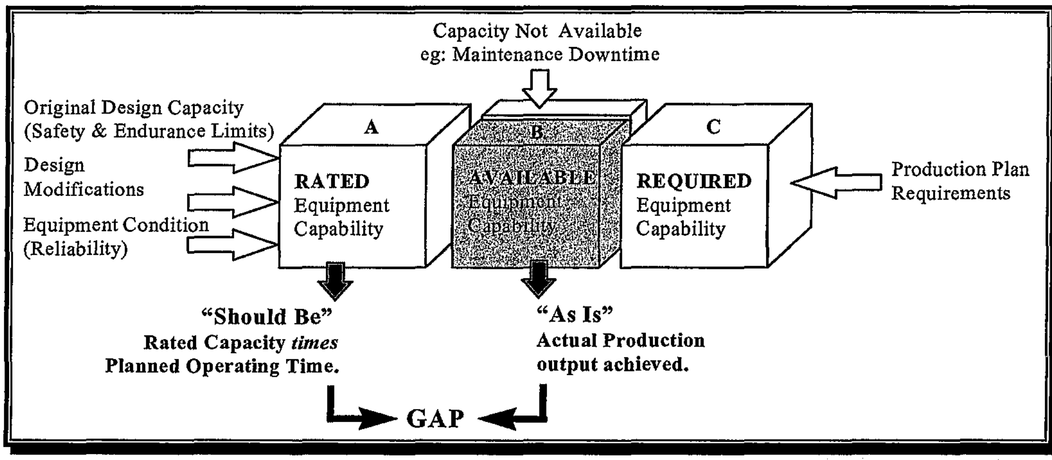

Figure 2.2 – Losses in Actual Production due to equipment capability (Katila, 2000).

The GAP between the actual and potential output from equipment is a measure of the total losses being suffered. The measure of Uptime illustrates the types of losses which cause this gap:

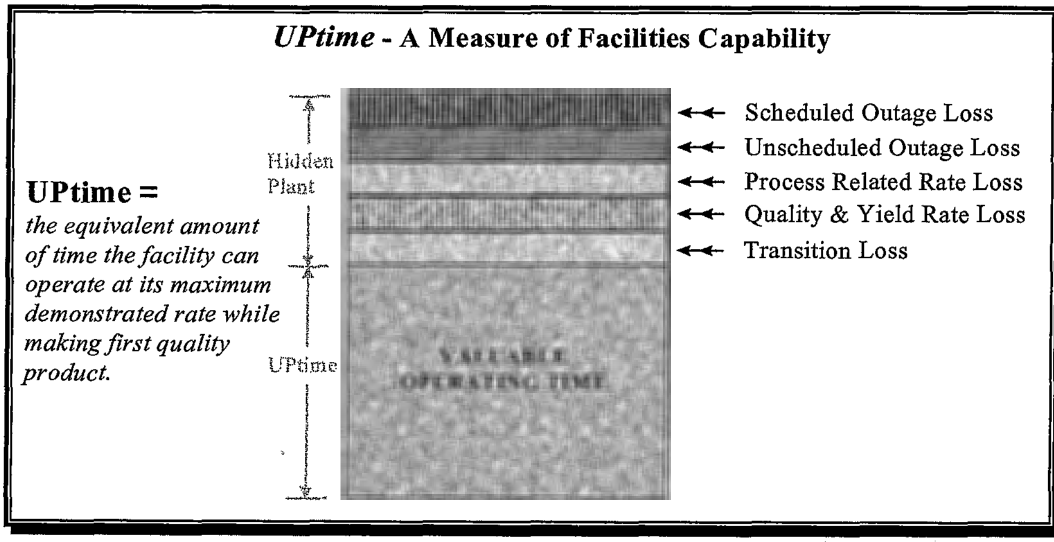

Figure 2.3 – A Measure of Facilities Capability (Reliability Web, 2001)

Jones et al (1997) call this gap the "hidden plant" - it reflects the additional production capacity which should be utilised without the need to increase capacity through capital expenditure. Ahmad & Benson (2000:36) define the measure for the "hidden plant" as follow:

$$Hidden\_Plant = Output \times \left(\frac{world\_class\_OEE}{actual\_OEE} - 1 \right)$$

2.2.5 Aligning Equipment Capability with the Business Strategy

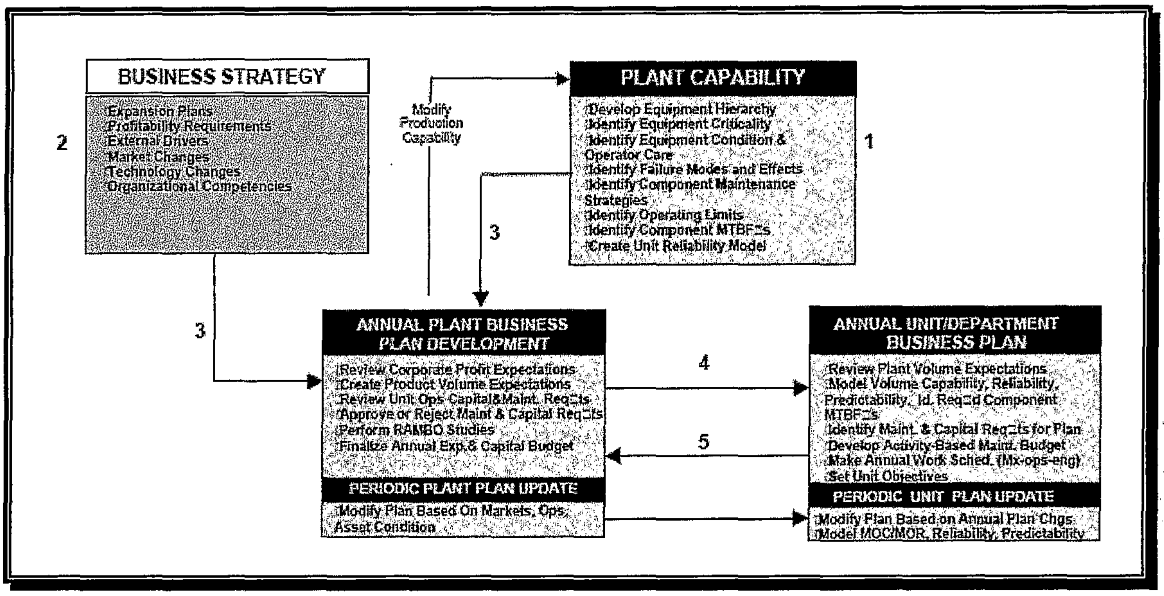

Figure 2.4 – Aligning Business Strategy with Equipment Capability (Peterson, 2000).

As illustrated in Figure 2.4, the equipment or plant capability plays an integral role in the development of the business strategies. With the planning and developing of this strategy it is important to have a comprehensive understanding of the capability of the equipment. With the capability not fully understood, it may lead to ineffective planning within strategy development resulting in future targets not being met. As illustrated, the process of business unit and departmental planning starts of with the overall business strategy and the equipment capability taken in consideration at the same time.

"Both the *equipment capability* and the business requirements are inputs to developing the annual plan. What is different here is that we have now studied the plant at a greater detail than ever before. We know what the right level of maintenance is historically, and can justify the activities and expenses. We are now considering the assets, their condition and capability, as well as our systems, human and automated, all as part of the annual planning process." (Peterson, 2000).

2.3 Assessing equipment throughput.

2.3.1 Equipment throughput

The fundamental driver for operations is tons produced per year. This figure is determined by the average tons per hour produced during the year and is a function of operating *capacity* and *equipment availability*. If *equipment availability* is low, then higher tonnage rates - perhaps exceeding the plant's *capability* - are required to meet annual production target. There is a fine balance between maintaining average tonnage rate and meeting the annual target.

For an operation with a nominal capacity of 320 tones per hour, an overall equipment availability of 89% is needed to meet an annual production target of say, 2,500,000 tons. If the average tonnage rate falls by just 5% to around 300 t/h then an *equipment availability* of over 95% is needed - a figure much harder to sustain.

The tonnage rate achieved is closely linked to overall equipment condition and performance.

2.3.2 Calculating overall equipment effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a good measure of equipment's overall condition and performance. This is essential to be measured and / or calculated prior to the development of the business strategy. It reflects how well equipment is actually utilised. It is also a value which can be compared (or benchmarked) with other operations to understand what the equipment should be capable of achieving.

The *OEE* measurement takes into account all of the major loss factors associated with *plant & equipment* as illustrated in Figure 2.5.

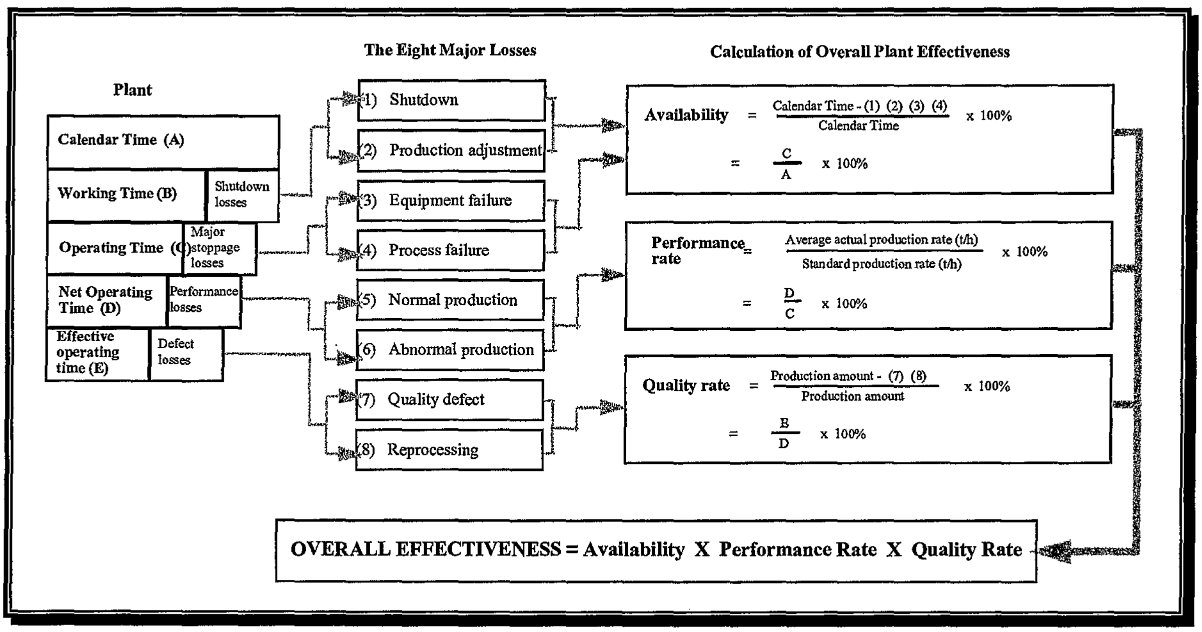

Figure 2.5 – Calculating Overall Equipment Effectiveness (Productivity Factory, 2001).

OEE = Availability x Performance Rate x Quality Rate

Availability: This can be improved by reducing amount of time which the equipment is out of service due to maintenance activities. This downtime can usually be reduced simply by working smarter with better planning and coordination of resources, and a better understanding of equipment condition.

Performance Rate: This can be improved through careful operation with a focus on process stability rather than the highest instantaneous rate (e.g.: to keep up the average) and with better planning and coordination of operational change-over, etc.

Quality Rate: This can be improved by eliminating the sources of defects such as poor machine settings, failure to calibrate control instrumentation, poor quality feed materials, and unpredicted equipment failures, etc.

2.4 Equipment (throughput) losses.

There are eight categories of losses which are widely recognised as being the major loss factors in equipment throughput. These are the losses used in calculation of overall equipment effectiveness (or Uptime) and they effect all standard performance measures. This is illustrated in Table 2.1 below:

The Eight Major Losses (as defined by JIPM - the Japan Institute of Plant Maintenance)			
Loss	**Definition**	**Units**	**Example**
1. Shutdown Loss	The time lost when production stops for planned shutdown maintenance or periodic servicing	Days	Shutdown work, periodic servicing, statutory inspections, inspections, general repair work, etc.
2. Production Adjustment Loss	The time lost when changes in supply and demand require adjustments to production plans	Days	Production-adjustment shutdown, inventory reduction shutdown.
3. Equipment Failure Loss	The time lost when equipment suddenly loses it's specified functions - eg: unplanned breakdowns	Hours	Failed pumps, burned-out motors, damaged bearings, broken shafts, etc.
4. Process Failure Loss	The time lost in shutdown due to external factors such as changes in chemical or physical properties of materials being processed, operating errors, defective raw materials, etc	Hours	Spills, blocks, dust scatter, mis-operation.
5. Normal Production Loss	Rate and time losses at plant start-up, shut-down or change-over	Rate decrease, Hours	Production rate reductions during warmup period after start-up, cooldown period before shutdown and product change-over, eg: product size or grade change, etc.
6. Abnormal Production Loss	Rate loss occuring when plant underperforms due to malfunctions and abnormalities.	Rate decrease	Low load operation, low speed operation, and operation at below standard production rate.
7. Quality Defect Loss	Losses due to producing rejectable product, physical loss of rejected product, financial losses due to production downgrading	Hours Tonnes Dollars	Physical and time losses due to making product that fails to meet quality standards
8. Reprocessing Loss	Recycling losses due to passing materials back through the process	Hours Tonnes Dollars	Recycling non-conforming product from the final process to the starting process to make it acceptable

Table 2.1: Eight major losses as listed by the JIPM (Middle East Technical University, 2005).

To address these losses, we need to understand:

- the significance of each loss factor to the business (e.g.: it's consequence);
- the cause - what's allowing it to occur, and;
- what can be done to avoid it from occurring.

One of the keys to improving overall business performance is to identify and measure the components of these losses. Each of these eight major loss categories will be discussed in more detail with a strong focus on the operations as discussed in Section 1.1 above.

The challenge for any organisation is to identify how to work together as a team to minimise the effect of these losses. Ring fencing maintenance within this regard is one of the major potholes in the drive to reduce these losses. An aligned effort between operations, maintenance and supporting functions is of essence when embarking on the loss elimination exercise.

By applying these losses to the area of analysis, a better understanding of the areas of measure can be obtained. It is essential to fully understand all of the major losses from both an operations and maintenance perspective (as described by the polarity matrix in Chapter 1) in the quest to solve the dilemma of the maintenance manager.

2.4.1 The causes of equipment throughput losses

In order to effectively define what should be measured in order to determine the effectiveness of a maintenance function / department, it is of essence to understand the origin of equipment throughput losses. This goes far beyond the normal losses of equipment breakdown and down time due to preventative and predictive maintenance activities (usually focused on by maintenance managers). The business must be seen as a whole to fully utilise the potential benefits to be gained from eliminating equipment throughput losses.

2.4.2 Shutdown losses

Shutdown Losses are the losses associated with planned equipment shutdowns for maintenance or periodic servicing. These losses are at a minimum in the ideal shutdown situation. However, in many cases shutdown performance is far from ideal and significant additional shutdown losses are experienced (Middle East Technical University, 2005).

These shutdown losses are often incurred because:

- the plant / equipment is stopped earlier or later than planned thereby upsetting the planned maintenance schedule;

- the shutdown duration exceeds the plan and thereby changes the planned production schedule, and;
- returning the plant to service requires a standard minimum set-up and stabilisation period which is not achieved due to work quality and commissioning difficulties.

The challenge is to identify how to work together as a team in planning and managing shutdowns better to minimise the effect of these losses.

2.4.3 Production adjustment losses

Production adjustment losses are the time and capacity losses incurred when the production rate (or throughput) is adjusted to allow for changes in market supply and demand (Middle East Technical University, 2005). This happens in periods when the equipment has to be operated at less than planned production rate.

Possible reasons for planned reductions in production rate include:

- Reduced market demand
- Product stockpiles full due to delayed or reduced shipping arrivals;
- Deliberate policy to run-down stockpile levels to reduce inventory costs
- Delayed arrival of raw materials due to supply problems.

In most cases, production adjustment losses are not attributable to standards of operation or the maintenance of equipment. Generally, they are caused by circumstances or problems outside of the business units' control.

Problems in the supply of raw materials or in the shipping of products may be caused by:

- adverse weather conditions,
- industrial problems in other industries or in other countries, or

- poor equipment performance in customers' or suppliers' organisations.

It is worth noting that if these problems are caused by the standard of operations and maintenance activities of suppliers' or customers' organisations - then if one can help them improve towards world's best practice – the business unit will indirectly help themselves.

2.4.4 Equipment failure losses

Equipment Failure Losses are the losses incurred when unplanned equipment failures are experienced. These can include production losses, safety / environmental problems, and equipment damage.

It is generally recognised that the repair of an unplanned equipment failure can cost up to eight times as much as the same repair done under planned conditions - and that excludes the costs of any consequential damage and lost production.

Each time an unplanned equipment failure occurs, the risk of incurring additional stop / start losses are experienced. The more frequent unplanned failures, the more they contribute to increased costs, throughput and quality problems.

It is in the best interests of all to understand the condition of equipment and to work together to prevent and / or eliminate all instances of unplanned equipment failure.

2.4.5 Process failure losses

Process Failure Losses are the time and capacity losses incurred when the production rate (or throughput) falls as a result of operational factors such as:

- changes in the chemical or physical properties of the materials being processed;

- defective raw materials;
- operating errors.

These losses are not caused by equipment condition faults, but can themselves be the cause of equipment condition deterioration. Possible reasons for process failure losses include:

- Poor quality raw materials / ore overloading plant circuits;
- Reduced throughput in size reducing operations due to harder feed materials (e.g.: in grinding, crushing operations);
- Losses due to operator errors in process (control) synchronisation leading to spills and or blockages in materials handling systems;
- Losses associated with equipment overload or over speed due to operator error.

In many cases, process failure losses can be incurred as a result of people not fully understanding the implications of their decisions and / or actions. For example:

- problems in raw materials specifications could arise because supply personnel are purchasing alternate, cheaper materials to "save" costs;
- operators are overloading parts of the plant in an attempt to "raise" production levels without knowing the full equipment design intent.

The challenge is to share specialist knowledge of the process, materials and equipment design specifications to ensure that collectively, all work together in the best long-term interests of the business as a whole.

2.4.6 Normal production losses

Normal production losses are the rate and time losses associated with normal plant start-up and shut-down procedures, and with tooling and / or product change-over procedures.

In the case of hot processes like submerged arc furnaces and blast furnace operations, the magnitude of these losses may depend on the planned duration of the shut-down and the work access requirements (e.g.: for major cooling & purging and then re-heating cycles).

The magnitude of these losses is generally part of the design of the equipment and its planned operating procedures. In many cases, this can make it difficult to achieve significant reductions without incurring capital expenditure in plant re-design.

However the magnitude of these losses is also related to the number of times that the shut-down / re-start cycle has to occur. The more often equipment has to be shut-down, the more often these losses are incurred. These losses can thus be reduced by:

- increasing the production (campaign) life of the equipment through careful operation and care of the equipment condition;
- reducing the number of product changes within the acceptable limits of customer service requirements and inventory control, and;
- doing high quality maintenance work to minimise unplanned failures.

2.4.7 Abnormal production losses

Abnormal production losses are the time and capacity losses incurred when the plant is running at reduced throughput (low load or low speed). These losses can be caused by equipment malfunctions, partial as well as complete failure, and / or other production abnormalities.

Possible reasons for abnormal production losses could include:

- operating at reduced load until the next planned shutdown because the equipment is indicating signs of advanced deterioration (e.g.: gearbox or bearings running hot or noisy);
- operating at reduced speed with the plant under manual control because the automatic control system is erratic;
- operating at reduced speed because of a shortage of operators and / or materials handling equipment (e.g.: forklift trucks), and
- operating at reduced speed or delaying plant start-up until after the next shift change (e.g.: take it easy and let the next shift do it).

2.4.8 Quality defect losses

Quality defect losses are the time, material and revenue losses incurred when the plant is producing poor quality product. This includes the cost of producing reject product, and the revenue losses associated with making sales of non-prime (or down-graded) quality products.

Possible reasons for quality defect losses could include:

- equipment failures (including malfunctions and drift from setting);
- poor initial set-up and calibration of equipment;
- poor quality raw materials, parts and services from outside suppliers, and
- inappropriate operation of the equipment and processes and failure to follow procedures.

Quality defect losses disrupt production plans and delivery schedules. These impact on quality from a customer service perspective. The ability to consistently make high quality products is a significant competitive advantage. Customers like to have reliable suppliers. A consistent supply of high quality products commands a value-pricing advantage and ultimately, a larger market share.

By always producing the maximum proportion of prime quality products, one can increase one's revenues for the same tonnage throughput, achieving a higher return on capital. Consistent production of high quality products helps maximise the value of a business.

2.4.9 Reprocessing losses

Reprocessing losses are the time and capacity losses incurred when materials have to be re-cycled through the same process. This can be as part of the normal production process, or it can be a result of producing non-prime quality products.

Typical examples of reprocessing losses include:

- excessive re-circulation of materials in crushing and screening or grinding (ore processing) operations;
- excessive scrap and off-cuts (cropping) in steel rolling operations;
- re-cycling reject materials (e.g.: un-saleable product fractions to furnaces), and
- additional work in "making good" second quality products (e.g. second pass of product through a process).

Whilst some processes require a degree of materials re-cycling as part of their design, there is clearly a cost incurred in terms of energy consumption and wear and tear on the equipment if the design re-cycle rates are exceeded. If the rate of material re-cycling is allowed to rise above the optimum design level, then the business is incurring a loss.

If reject products need to be processed further (materials) for recycling, a further loss is incurred in having to do that work. A reprocessing loss is also incurred when re-cycled materials are re-processed. This is because the equipment could otherwise be available to produce "prime first time" products. The products made from re-cycled rejects cost "twice as much" to produce as "prime first time" products (excluding the raw material cost).

There is often believed that re-cycling sub-standard products is a cost saving because use is made of otherwise rejected materials. Whilst this may be true, the real cost saving challenge is to avoid making the reject products in the first place.

2.5 Maintenance Key Performance Indicators (KPIs)

2.5.1 Measuring equipment (throughput) losses.

The Uptime Model for measuring losses

The UP-time model, (Reliability Web, 2001), is an effective way of representing equipment performance. It compares current performance (in terms of throughput) with what the equipment should be achieving. The illustration below shows how this concept can be used to display (and measure) performance. The detail this measure goes to requires a sophisticated level of measurement.

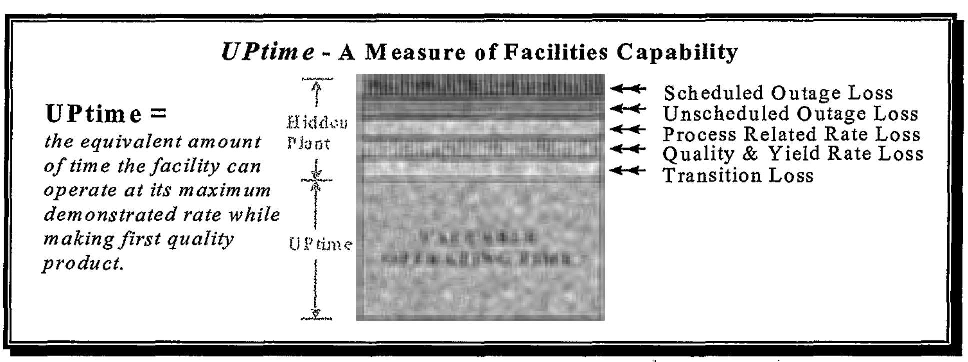

Figure 2.6 – UP-Time as a measure of Equipment Capability (Reliability Web, 2001)

A common problem is that performance measuring is often not done accurately. However, with some creative thought, the UP-time model can effectively be used to represent plant performance - as illustrated if Figure 2.7 below:

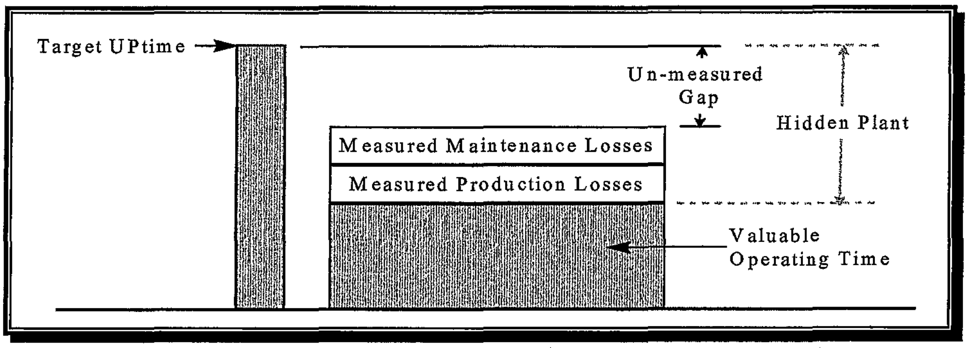

Figure 2.7 – Illustration of the unmeasured losses

Without always realising, the UP-time target is defined in the production schedules. The valuable operating time can be determined with a simple formula. Measures of losses associated with unscheduled maintenance and production downtime is usually available. By simple difference, a measure of the combined total of any other losses incurred can be obtained.

Use of this model will make the magnitude of losses visible and should serve as a strong motivation for team focused improvement activities.

Showing measurable losses

The Measurable Losses are those losses which are measured and tracked by the equipment operations and maintenance people. These will be different from site to site depending on management requirements and the measurement systems and procedures in use.

The most common form of measurement of these losses is the recording of downtime or production delays. The systems used to record this data include downtime systems, delay recording systems, event monitoring systems, and incident management systems. Typically these systems produce reports which provide an analysis of lost production time. Note that it may not be easy to categorise the measured losses accurately in line with the "eight major losses". Equally, there may be some loss categories which are not measured at all.

Measuring the 'hidden plant'.

According to Ahmad & Benson, (2000:35) the 'hidden plant' is the amount of extra production that could be achieved from a particular process plant if it was performing at world-class standards. The gap that exists between the actual production and the possible production is defined and quantified by the losses as previously discussed. Obviously, not all of these losses are always preventable. Some will be due to circumstances outside of the business unit's control - such as production adjustment losses due to falls in market demand. Many of these losses are due to inefficiencies in the way work is performed and are preventable - or at least, can be reduced substantially.

The magnitude of these losses is surprisingly easy to measure Appling the UP-time model. They are represented by the gap between the target UP-time value and the valuable operating time.

There are a few important points to consider when looking at the completed UP-time model:

- the target uptime is simply the budgeted operating time after allowing for scheduled maintenance overhauls and product change-overs, etc.;
- the valuable operating time is simply based on the best production rates which has been proven and can be achieved (albeit not continuously);
- some measures of production downtime usually exists but are not always as complete and as detailed as is needed;
- there is a 'gap' between what is done, and what is known to be possible (and able) to do (if the 'gap' is negative then the targets are probably too low).

The visibility of the gap in this UP-time model should serve as a significant motivator for improvement. The challenge for us is to work together to identify and eliminate the causes of these losses - whether currently measured or un-measured.

2.5.2 Identifying effective maintenance process KPIs.

Maintenance outcome KPIs (eg: availability) is needed to indicate how one performed during the last reporting period, and process KPIs is needed to help to control how one is going to perform during the next and future periods.

Closed loop KPI design

There are several things that need to be done to make sure that maintenance process KPIs will provide useful information. Perhaps the most obvious is to collect good quality data from which accurate KPI values can be calculated. More importantly however, consideration needs to be given to how process KPIs are designed and specified in the first place.

The key to specifying effective process KPIs is to use a closed loop design. Rather than just defining how KPI values will be calculated, this approach forces to consider a number of other issues associated with what the result means and how it will interpreted and used.

In addition to specifying how the KPI value will be calculated, the closed loop design requires additional thought to:

- specify a target value based on a maintenance business plan or benchmark;
- determine what factors (or inputs) can influence the KPI value and the cause and effect relationships between them;
- understand what a variance from target means – e.g.: is it good or bad & what is its potential effect on the business;
- understand what can cause the variance and specify appropriate actions which can be taken to correct "off target" values, and;
- identify who will be responsible for follow-up on the actions.

If one cannot specify up-front how to apply the KPI information to help improve the business performance (outcomes) – the question should be asked - should the KPI be used at all?

Three key elements of effective KPIs are closed loop design, ownership of the KPI information produced, and quality of the data from which the KPI values are calculated.

2.5.3 Determining KPIs to measure.

A maintenance process KPI is basically a control mechanism. Its output is a measurement which, when outside of its specified tolerance, should initiate corrective action by the people concerned. Process KPIs, therefore, need to be targeted to measure the maintenance inputs which specifically need to be controlled.

Identifying maintenance measure and control

Before defining maintenance process KPIs, it is essential to first establish what inputs need to be controlled, and why. We also need to check to see if suitable data is available to support this measurement and control. Obviously, if the data is not available, the first step will be to start to capture and record it.

Inputs to be measured and controlled could include:

- Workload (Backlog);
- Labour delays;
- Re-work (not doing work correct the first time);
- Spares availability;
- Schedule compliance;
- Planned work percentage;
- Equipment delays;
- Failure analysis.

Part of the process of deciding what needs to be measured and controlled from a particular maintenance input, is to determine how the resulting measure (KPI) is going to be used. To be able to use it effectively, two things need to be done:

- identify all the inputs that can influence the measured result (the KPI value), and;
- understand how these inputs impact on the result.

This process is displayed in the question set developed to measure different aspects of maintenance (Appendix B).

In this process RCM plays an important role. The outcomes of RCM, according to Moubray (1997:292) results in three tangible outcomes:

- Maintenance schedules, to be done by maintenance departments;
- revised operating procedures for the operator of the asset;
- a list of areas where once-off changes must be made to the design of the asset.

2.5.4 Developing a closed loop design for KPIs.

Setting appropriate targets

The primary purpose of a KPI is to provide a measure of performance. For that measurement to have any useful meaning, it needs to be compared with a target. So, once decided what to measure, the first step in KPI design is to establish the target level of performance that should be achieved. "If you don't have a goal - you can't score".

An easy way to establish a target for a maintenance process KPI is to look for a benchmark (industry standard) that should be aimed for. Alternately, one might use the first result as the current benchmark, and target a percentage improvement to be achieved over a period of time. As this is the first evaluation, it will serve as the baseline for future improvement.

One of the key considerations in setting KPI targets is to choose values that are achievable. These targets should be stretched to ensure it is not too easy to achieve. Whilst ultimately, everyone wants to lead in world's best practice, there will be times when that level of performance is either inappropriate for the business, or simply unachievable within the foreseeable future.

Constant failure to achieve a target is a significant de-motivator. It is far better to set a target that can be achieved and then set a higher target to stimulate further improvement.

<u>The closed loop KPI design</u>

Having calculated a KPI result as a variance from target, the following is needed:

- decide if the variance of the KPI is significant;
- validate the result;
- investigate the causes of an invalid or off-target result, and;
- initiate, implement and track appropriate corrective actions.

Although the tracking of the improvement initiatives will eventually reflect in the KPI, it is in some cases of interest to track specific improvements separately.

2.6 Key components of Maintenance Work Control.

"Maintenance Work Control" is the process through which the maintenance work-load is planned and managed using "job requests" and "work orders" in a computer system such as SAP. According to Wild (1991:683) the maintenance planning enables the maintenance manager to specify when and where the maintenance work is to be executed. What needs to be added to this definition is what type of maintenance activity needs to be carried out. Wild (1991:658) further defines the types of maintenance work as inspections, service, preventative maintenance and repair.

Effective work control is a basic requirement for effective equipment management. This includes maintenance, operations and supply, and if done well, leads to sustainable and profitable business outcomes.

2.6.1 Work control concepts

A common cause of ineffective use of work control systems, lies in the diversity of views people have on why it is needed and how it should work. It is usually preferred to argue about process, roles and responsibilities rather than cooperate in the commitment to use systems and processes properly.

2.6.2 Key concepts behind managing work flow

One could argue many key reasons for managing maintenance through some form of work control system. Reasons commonly suggested include:

- to make sure that jobs required to be done, are done (e.g.: not forgotten);
- to be reminded when routine preventive maintenance jobs are due; and,
- to be able to collect history for future analysis.

The beliefs in these reasons are usually driven by experience and current systems usage. Commonly, work is identified, planned and controlled within a fairly short time horizon.

In reality however, the success of maintenance (or any other type of logistics management) depends heavily on the ability to plan ahead in order to effectively organise and manage the necessary resources effectively.

Excepting urgent jobs which may by-pass the system, every job should flow through the pipeline of *job identification, authorisation, estimating* and *planning* steps, result in ineffective resource planning and job execution. This in turn results in losses as previously discussed. This "flow" ends up in a conceptual "bucket" which represents the total outstanding work to be done. If this amount of work cannot be defined and measured well ahead of time, there exists little hope of effective planning, organising and managing the resources required to do it.

2.6.3 The importance of effective planning

Planning ahead in maintenance is important because, apart from helping maintenance personnel to be in control of the equipment condition and performance, the following benefits are gained:

- it allows us to forecast and organise the appropriate resources to do the work;
- it also helps maximise the efficiency with which we carry out that work resulting in the minimising of losses and
- downtime of equipment that may be required can effectively be integrated with the production planning and schedules.

People actually carrying out the maintenance work suffer many logistical difficulties in using their time effectively.

Hellriegel et al. (2002:8) define the managerial functions as *planning, organising, leading* and *controlling*. Effective planning cannot be seen apart from the rest of these managerial functions. In order to gain the maximum result from effective planning, it needs to be followed through with effective organising, leading and control.

2.7 How to measure the softer side of maintenance.

2.7.1 Recognising the difference between hard and soft measures

The maintenance process KPIs that are used are generally derived from work orders and costs collected in computerised systems as concentrated on in previous sections of this chapter. One of the problems with these data driven KPIs is that they do not usually provide any real measure of the "softer" issues. The softer issues are more related to the people and the effectiveness of the team function. These measures could include:

- how well equipment is looked after;
- how effective the team work is;
- how good house-keeping is;
- how satisfying the work place is;
- the drive towards a "TPM" environment.

These issues are not about hard facts and data collected in computer databases, they are about *people*. They are about attitudes, the way people work together, and the way they care about each other, the equipment and the work environment.

These measures are referred to as soft measures because they can only really be assessed subjectively by inspecting the workplace, and by researching people's opinions. Routine safety audits are a good example of this kind of "soft KPI review".

2.7.2 The importance of softer (TPM) measures

The foundations of the TPM philosophy lie in a deeper understanding of the causes of equipment failures. Extensive research over many different industries has shown that two types of failures are suffered (Ledet, 2004):

- Normal wear-out, and;
- Accelerated Degradation

Normal wear-out occurs when equipment operates under its original design conditions and is maintained appropriately. Under these conditions, failure only occurs through natural deterioration at the end of the expected design life (even if the life-span itself is random).

Accelerated deterioration - Under this regime, equipment never reaches its design life. Rather, it fails prematurely due to human intervention such as poor installation, poor operation, inappropriate maintenance, and the use of poor quality parts and materials, etc.

To combat failures due to accelerated deterioration, a working environment, where the causes of premature failure are not allowed to occur, needs to be created. This to create a hazard free working environment in order to promote safety. In the same way, it is needed to create a defect free working environment to promote equipment and process reliability.

These measures of the "softer side of maintenance" should not be seen as a category / element of measure alone, but needs to be integrated with the other measures already discussed.

2.8 Profit Centered Maintenance

The last distinguishing characteristic, Profit Centered Maintenance, integrates cultural, process, and attitude attributes within the plant organisation to drive business decision-making processes (Peters, 2002).

More specifically, profit centered maintenance is:

- A culture in which decisions related to maintenance and reliability have a solid business basis and grounding in probability. Includes alignment of staff, technicians, operations, maintenance, and management.
- A system of process controls that assure effectiveness of maintenance and reliability activities.
- A mindset that challenges the status quo and demands continuous improvement, outstanding return on investment, waste elimination, and process excellence in operating predictability (i.e. reliable throughput, quality, and cost).

Together, these attributes cause unwillingness in an organisation to accept decisions without a solid business basis and implementation plan. Just as a plant culture can become unwilling to accept equipment failures (Systematic Failure Elimination); a plant culture can also become biased against decision making processes that are based on mere hope for a desired outcome. This "cost of hope" is eliminated as decisions and actions become data driven and profit centered with an underlying understanding that real life situations are gray rather than black and white and therefore require a probabilistic perspective.

2.9 Conclusion

By understanding equipment from a loss perspective, effective focus can be given to aspects which need to be measured in order to effectively manage the assets towards the higher goal of optimal business benefit. These aspects can now easily be expressed in terms of the already defined business drivers of the organisation.

From the previous discussion it is important to realise that results achieved from management actions required by the equipment (usually best defined by the

OEM), can only be seen over the medium to long term. This still remains a challenge when managing the maintenance manager's dilemma.

Theory needs to be integrated with a credible well defined method of measure, in order to ensure future buy in from interested parties within the manufacturing process.