Robust Measures for Asset Management

A concise set of measures that support business objectives and attract investment in maintenance & reliability

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December, 2022

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1. Introduction

Asset Management, as described by experts and practitioners, is about balancing technical commercial and risk factors to ensure that physical assets are capable of performing the required tasks.

However, this paper introduces the theme of *asset performance* as an additional ingredient that focuses Asset Management upon **wealth creation** in the industrial context.

The term "**Asset Performance Management**" is used in this document to span the disciplines of operations, maintenance, logistics and technical support.

2. Definitions

Asset Property including apparatus, buildings, land, equipment, fixtures, machinery, systems and resources that have the purpose of providing an economic and/or social benefit.

Asset Effectiveness The degree to which the asset fulfils its purpose. Economically, it is the rate of wealth creation that an asset can sustain, year by year, throughout its life. Asset Effectiveness is a "business level" concept, and is measured financially by ratios such as Return on Capital Employed, Return on Assets, Return on Net Assets, etc.

Asset Management The actions, from the first realization of a need for a new asset to the final recycling of the disposed asset, which ensure that the asset safely achieves the business objectives.

Asset Performance The degree to which the asset carries out its intended function, measured against predefined criteria and/or standards. Asset Performance is a "functional unit level" concept, and is measured technically by ratios such as Utilization, Uptime, Delivery Performance, and Overall Equipment Effectiveness.

There are many dimensions to "performance". Whatever the dimension, the only real performance is that which is measured in ***real time.*** All other measures are simply summaries, averages, or higher-level combinations of summary information.

The further away from real-time a performance measure is, the less able it is to influence the actual performance of a working asset. For example, an end-of-month summary report has no chance of influencing activities in week 2 of that month.

Asset Performance Management Assuring that an asset safely performs its intended function over the calendar period of time that the asset is required to operate. Asset Performance Management consists of:

1. assuring the performance of assets in each short time period. This requires attention to precision and detail in the short term, in the disciplines of operations, logistics, reliability, and technical support (product and process).
2. controlling the risks of operating those assets over time. This requires careful assessment of performance, and projection of performance over a longer term. Risk mitigation strategies manifest as standard operating, and preventive maintenance procedures.

Risk The effect of uncertainty that may impact upon the objectives (ISO 31000:2018). *Risk is about the future*, and is estimated (or conjectured) by the aspects of Consequence, and Likelihood.

Risk Management The process of planning, organising, directing, and controlling the resources and activities of the organisation, in order to gain from potential opportunities whilst minimizing the adverse effects of accidental losses.

Maintenance A general term with multiple definitions and interpretations. The use of this term will be minimized here, in order to avoid misunderstandings arising from widely varying experiences and maturities across many industries.

The term "maintenance" will be used in reference to work type, or work actions planned, performed, and recorded.

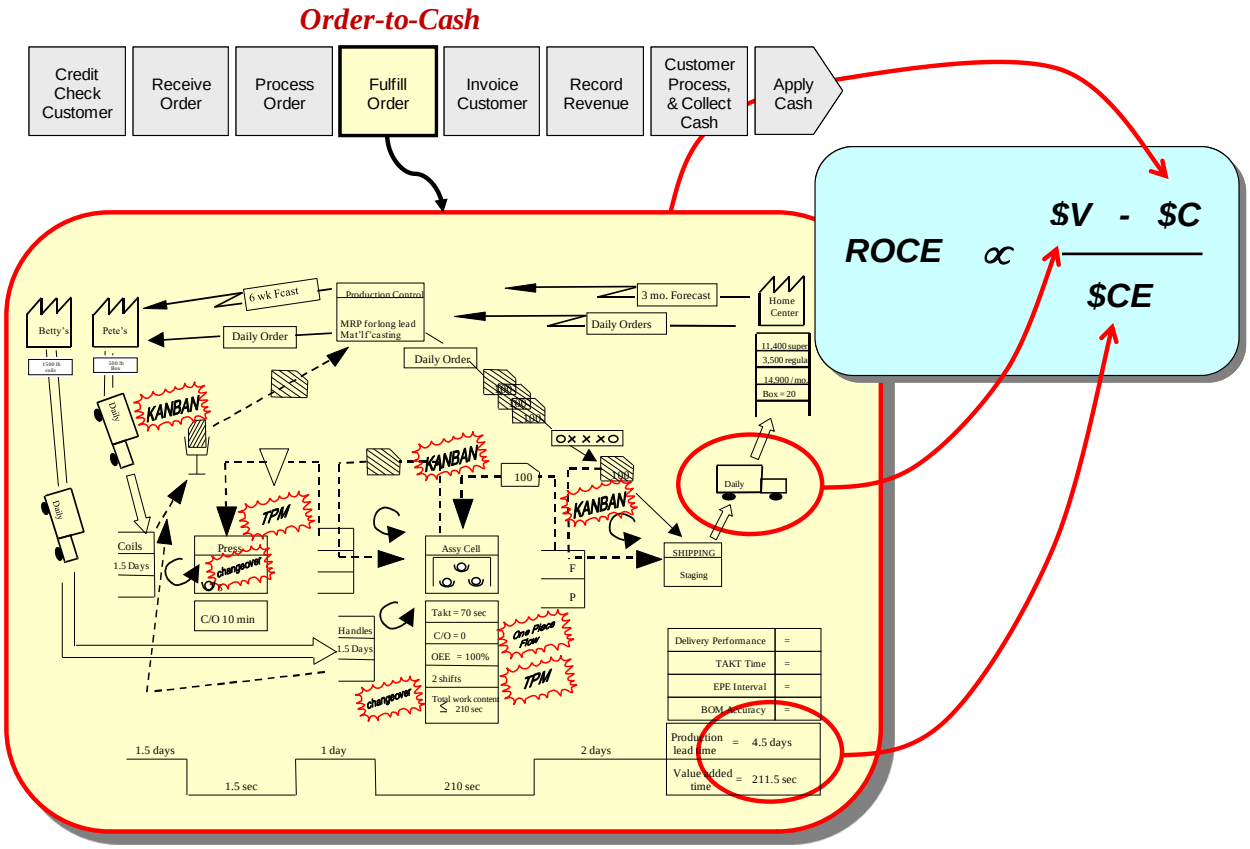
3. Measures of Effectiveness and Performance

3.1 Measure of Asset Effectiveness

In the order-to-cash cycle of businesses with large and complex assets, the "fulfill order" phase of manufacture is usually the value-adding transformation. The objective of the "fulfill order" phase is to:

"deliver exactly *what* is wanted, exactly *when* it is wanted,

with exactly *the quality* that is expected:



ROCE is an overall measure of the effectiveness of the asset including all the activity required in operating the asset to "fulfill order".

ROCE = Return on Capital Employed, where for any time period:

$V = The value of the output delivered,

$C = The fixed and variable costs of the entire process,

$CE = Capital Employed – the amount of long and short term debts and equity required to sustain the operation. (Note here, that the inventory carried is equivalent to capital employed with a zero rate of return).

3.2 Measures of Asset Performance

Asset Performance The degree to which the asset carries out its intended function, measured against predefined criteria and/or standards. Asset Performance is a "functional unit level" concept, and is measured technically by ratios such as Utilization, Uptime, Delivery Performance, and Overall Equipment Effectiveness.

Asset Performance is usually associated with the "value-adding transformation" process, and therefore directly influences the value of the output delivered ($V) in the ROCE expression above.

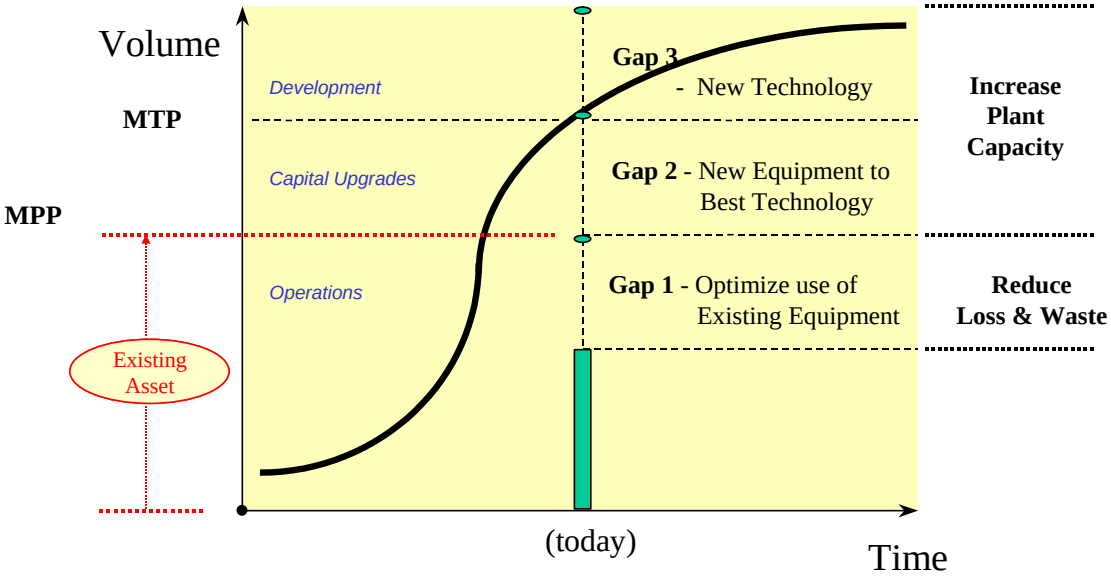
The next diagram below illustrates the three basic methods for improving the capacity *(or "intended function")* of an asset that is tasked with delivering a volume of output over time. In the life-cycle of the technology employed, the curve in the diagram represents the conceptual "experience-curve" – implying

that capacity improves over time though human learning and application; and the bar represents the current level of output.

The three basic methods of improving capacity are:

1. Gap 1 – Improve asset performance (as measured by volume per short time period), by reducing loss and waste.
2. Gap 2 – Capital expansion – increase the power, quantity, and/or dimensions of the asset.
3. Gap 3 – Research and development – extend the technology itself.

Increasing "Asset Performance" is the extent to which GAP 1 is minimized".



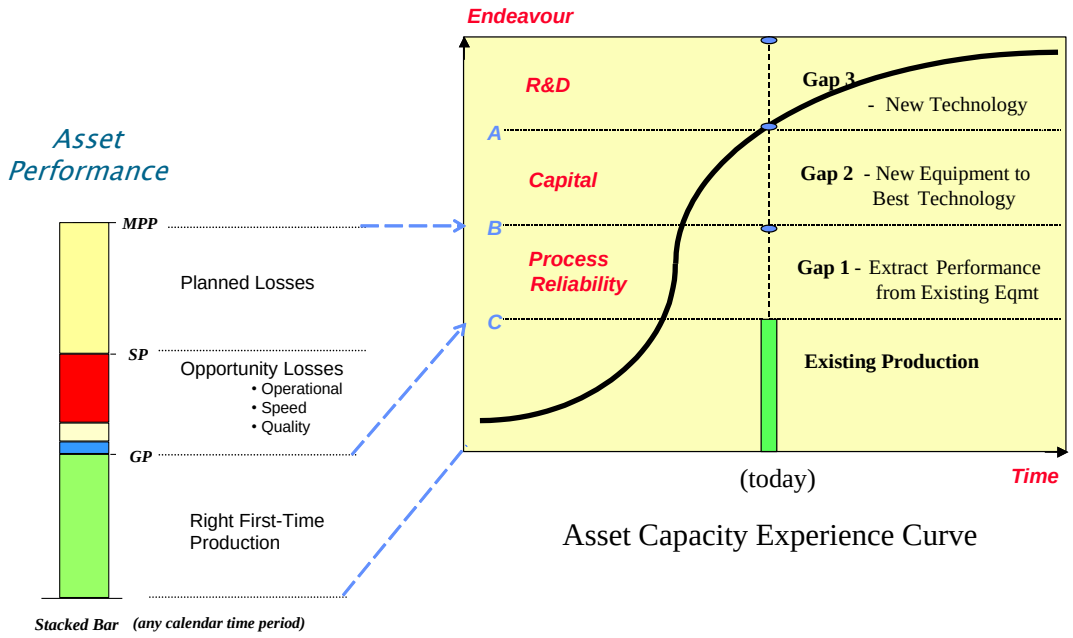
The level labeled **MTP** (Maximum Theoretical Production) – is the best production quantity that current technology could deliver, if the best available technology were installed within the asset today.

The point labeled **MPP** (Maximum Possible Production) – is the best production quantity that the **existing** asset can deliver *as installed*. Measured over a longer period, typical large and complex industrial plants will deliver between 50 and 90 percent of MPP, often with daily variations between actual and expected production.

The next diagram illustrates the types of losses that accumulate in Gap 1. These represent losses in two broad categories:

a. *Planned Losses* – production quantities that management sacrifice (decide not to produce) due to lack of demand, or for planned reasons such as outages, downtime, etc.

b. *Opportunity Losses,* the production losses that can never be recovered, due to operational and/or maintenance reasons (slowdowns, malfunctions, poor quality).



Asset Capacity Experience Curve

Measures of Asset Performance are easily derived as **ratios of production quantities**:

TEEP — **Total Effective Equipment Performance** ..... (aka Utilization or Uptime)

= **GP / MPP** — the ratio of the amount of [Right-First-Time] good product (GP), to the maximum amount that could have been produced (MPP). Maximum Possible Production (MPP) is attained if the manufacturing system operates perfectly and continuously, at its expected rate of production, for the total calendar time under consideration.

OEE — **Overall Equipment Effectiveness**

= **GP / SP** — the ratio of the amount of good product (GP), to the amount that is expected to be produced (SP). Scheduled Production (SP) is attained if the manufacturing system operates perfectly and continuously, at its expected rate of production, for the scheduled production time under consideration. That is, when the planned non-production quantity is excluded.

DP — **Delivery Performance**

the ratio "Output Made / Output Expected" over a specific time period (day, or week, or campaign time). DP is equivalent to OEE (Overall Equipment Effectiveness) when OEE is expressed in units of production.

DOI — **Days of Inventory**

The ratio: $Value of Current Inventory / $Sales per day

SCV — **Supply Chain Velocity**

another name for DOI (Days of Inventory)

4. Measuring the Objectives of Asset Management

4.1 Prime Objectives

The overarching purpose is to maximize the effectiveness of productive assets. This is done by capturing the benefits of **Asset Effectiveness** whilst controlling the **Risks** to the business over the asset's life.

Asset Effectiveness is measured by ROCE (Return on Capital Employed), which has three components that can be influenced. These three components can therefore be regarded as *"Prime Objectives"* of Asset Management.

$V = The value of the output delivered, Unit of measure: $

$C = The fixed and variable costs of the entire process, Unit of measure: $

$CE = Capital Employed – the amount of long and short term debts and equity required to sustain the operation, Where: Unit of measure: $

Where ROCE = Return on Capital Employed Unit of measure: %

≃ ($V – $C) / $CE

Risk The fourth *"Prime Objective"* of Asset Management is to manage the risk. The risk profile of a site or business can be summarized in a single composite measure called **Overall Risk Index** which summarizes the risk assessments across all risk categories (People, Asset Productivity, Support Systems).

LIKELIHOOD					
A Almost Certain (Over 30%)					
B Likely (10% to 30%)	37		8		
C Some Chance (3% to 10%)	10 24 32	15 27 29 35 38	3 4 12 22 30 33		
D Unlikely (1% to 3%)	17 19 39	1 2 18 26 36	5 6 21 23 25 28	20 31 34	
E Rare (up to 1%)		13	7 9 11 14	16	
Probability of Event Happening in a Single Year	**1** Noticeable	**2** Important	**3** Serious	**4** Major	**5** Catastrophic
	CONSEQUENCE (BUSINESS IMPACT)				
	$10k	$100k	$1m	$10m	$100m

Overall Risk Index Each individual risk assessment (numbered above) is assigned a risk value in dollars, according to its position in the profile. The dollar value is notionally assigned as ($Consequence X Likelihood)

Eg, Risk#8 has a $ value = $1m X 30% = $300K

The Risk Index for the site is the Sum of all the Risk values.

This Risk Index approach may be applied to a project, an area, a site, or an entire business. Providing the risk assessment process is consistent over time, the index trend will demonstrate the effectiveness of the risk management strategies applied.

As applied to the "Risk" Prime Objective, this measure may be labeled as the *""Overall Risk Index".*

4.2 Functional Objectives

In the context of an existing plant that is operated well, but *without* access to capital as the means of increasing capacity, there are six "critical success factors" contributing to the Prime Objectives. If any one of the six fail, then the likelihood of degrading operations is high, and chances of achieving the Prime Objectives simultaneously are greatly diminished.

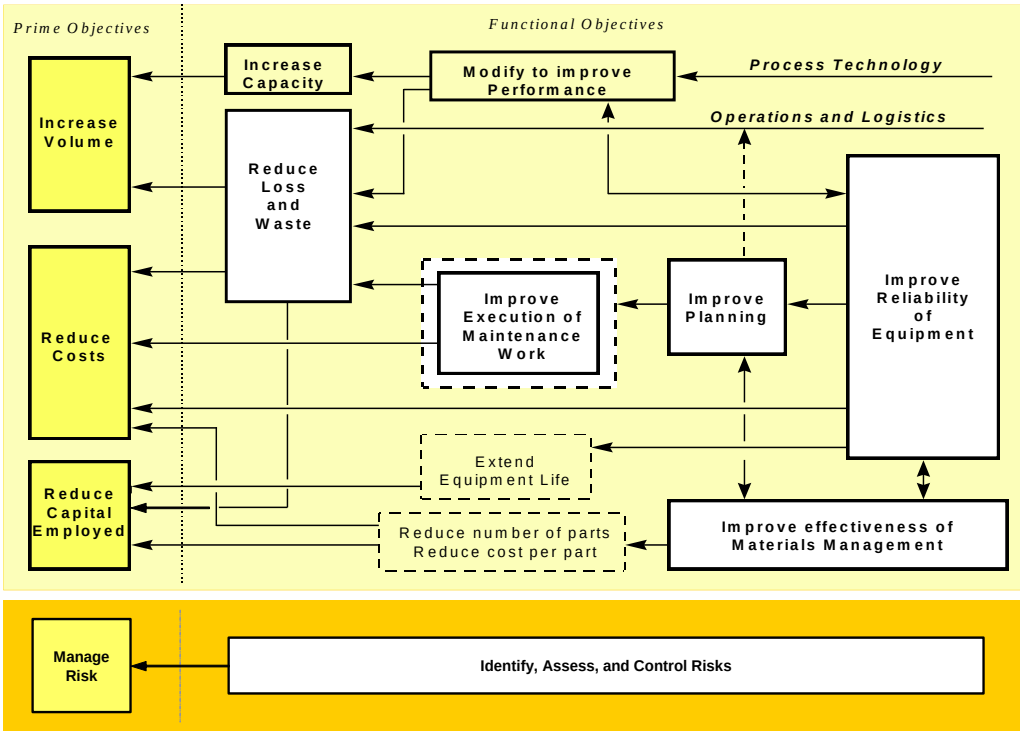
The six critical success factors are:

- management of loss and waste,
- reliability of the equipment,
- planning of maintenance work,
- execution of maintenance work,
- management of spare parts,
- assessment and control of risk

To meet the Prime Objectives, these factors therefore come into focus as functional objectives of asset management.

That is, the **Functional Objectives** *enable* the achievement of the Prime Objectives. The relationship between these objectives is illustrated in the diagram below. See Appendix A for a detailed explanation of linkages.

Asset Management Objectives



4.3 Measures for Functional Objectives

Each of the functional objectives above is assigned at least one measure that demonstrates achievement in each of two dimensions:

- Health Measure – the condition or status of the object that is being measured.
- Process Measure – the management process or strategy that is attempting to positively impact the objective.

The measures are summarized in the table below, and expanded in the description that follows the table.

Functional Area	*Health Measure (Condition or Status)*	*Process Measure (Management Activity)*
Loss & Waste	• Daily Quantity of Loss (in production units) per category of loss	• Daily OEE • Daily variation in OEE
Maintenance Work Execution	• Rework (non-conforming quality)	• Schedule Compliance
Planning	• Workload compliance per Work Type. • Budget compliance per Work Type.	• Planned / Total Work % • Injected Work (Manhours)
Materials and Spare Parts	• Stock Level Accuracy • Condition Score (critical parts).	• Percent of Equipment Register with BOM (Bill of Material) and linked to Materials Catalog.
Reliability of the productive Asset	• Quantity of Loss (in production units) attributed to equipment malfunction. • Condition Score for critical equipment.	• Number of Root Cause Analyses conducted per week. • Number and recency of Condition-based Risk Assessments for critical equipment
Overall Risk	• Risk Index per area	• Active Risk Register

4.4 Description of Functional Measures

4.4.1 Measures for Loss and Waste

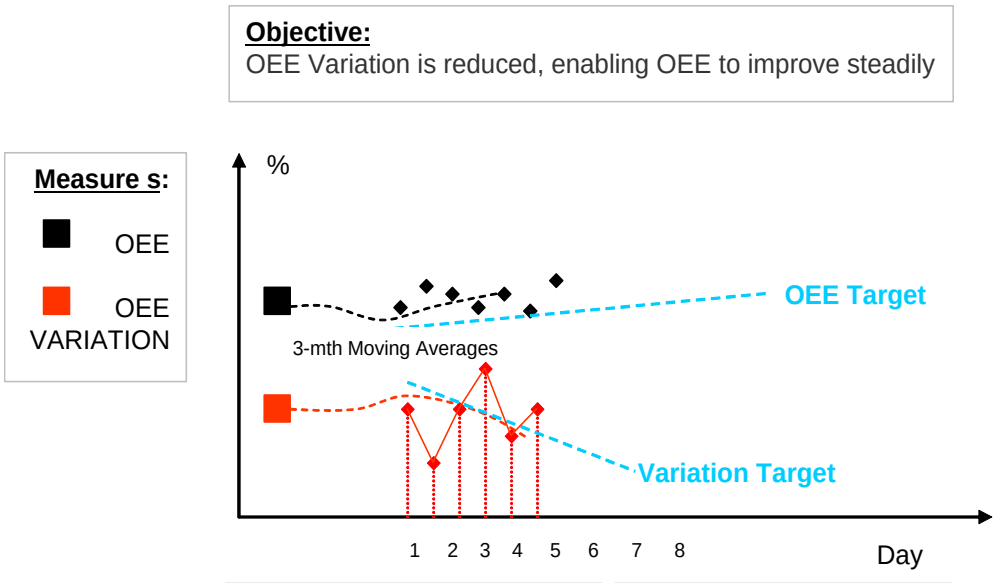
Health Measure **Daily Quantity of Loss (in units of production) per loss category.**

See Appendix B for Examples of Loss Categories & Types

Process Measure **Daily OEE (Overall Equipment Effectiveness)**

Process Measure **Daily variation in OEE**

As an organisation evolves, monitoring OEE and OEE variation will decrease from long periods (monthly, weekly), through to daily or by shift, then on to continuous (near real-time) measurement as variation is minimized. An example format is shown in the chart below:



Daily OEE, with Variation in OEE (not to scale)

4.4.2 Measures for Maintenance Execution

Health Measure **Rework**

The number of manhours per week (and/or number of events) where resources are required to repeat, repair or recommission equipment within a threshold of "**x**" hours or days after completing the original task. The number of manhours per week (and/or number of events) should decrease with continuous improvement over time.

Process Measure **Schedule Attainment**

The proportion of scheduled work that is completed satisfactorily during the scheduling period (usually one week). This applies for the ongoing workload, as well as separately for major and minor shutdowns.

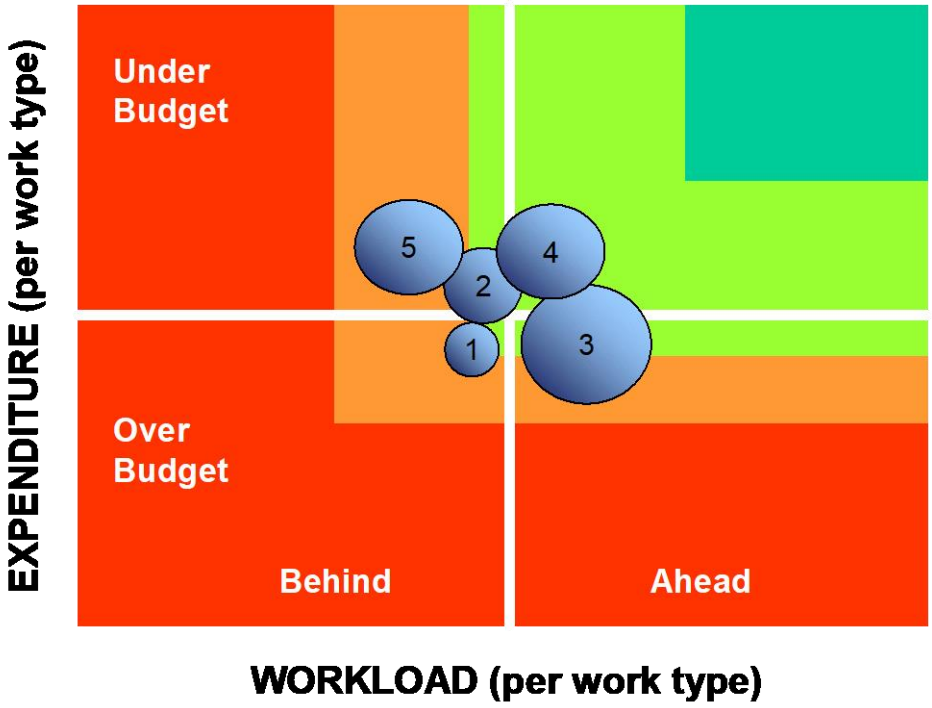
4.4.3 Measures for Maintenance Planning

Health Measure **Workload Compliance**

Health Measure **Budget Compliance**

A competent asset manager will have a long-range plan (over at least one major shutdown cycle of say, 10 years). This "life maintenance plan" will be accurately risk-ranked, planned and costed for the year ahead. The approved risk-ranked budget reflects the expected workload across each of the "Maintenance Work Types" (see section 4.6) for each organisational area. The annual workload is then granulated into monthly and weekly packages for detailed planning and execution.

Both Workload Compliance (manhours ahead/behind plan) and Budget Compliance (ahead/behind plan) can be summarized on the same chart, with magnitude of the budget components (for each Work Type) indicated by the size of the bubbles, and the tolerance to variation in workload completion and expenditure indicated by the coloured zones, as shown below:



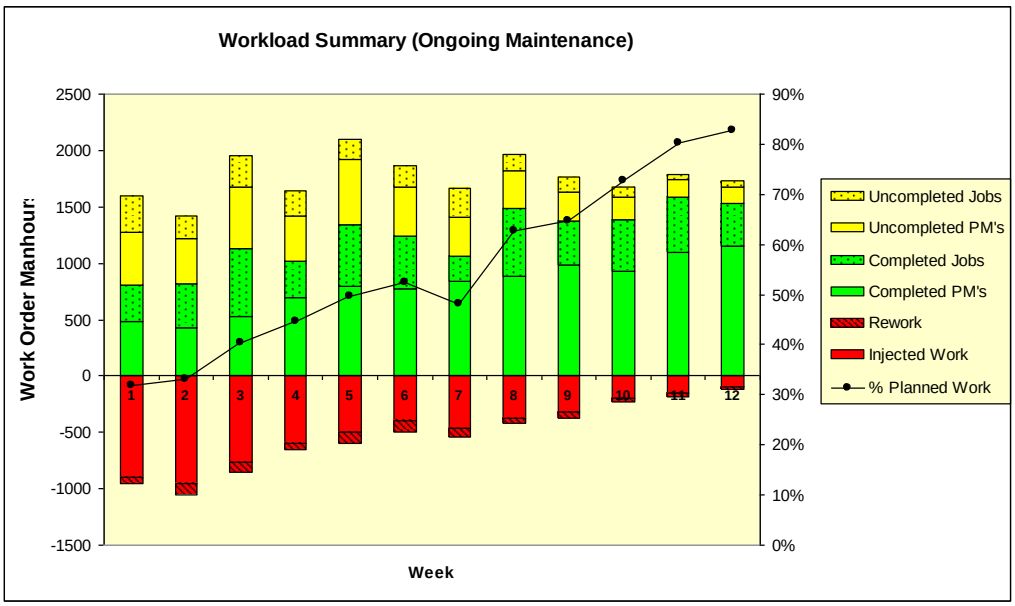
Process Measure **Planned Work %**

The amount of work (in manhours) planned and completed in the scheduled work period, as a percentage of the total workload (in manhours).

Process Measure **Injected Work (manhours)**

The amount of work undertaken (in manhours) that is forced into the scheduled work period, after the planned scope of work had been approved (prior to commencement of the scheduled period). Even if the additional forced work has been properly planned, it is still classified as "Injected" as it has disrupted the agreed workload for the period.

Both measures require ALL work-hours to be recorded. The measures may be illustrated in the combined workload bar-chart as shown below:



Work planned but not completed during the reporting period
Work Completed as planned during the reporting period
Work Injected into the reporting period (outside of plan)

4.4.4 Measures for (Maintenance) Materials & Parts Management

Health Measure **Stock Accuracy**

An ongoing (real-time) register of discrepancies (non-conformances) on the population of actual transactions, plus a sample from periodic spot audits. Absolute accuracy is verified by occasional stocktake.

Health Measure **Condition Score**

Regular assessment of the "fit-for-purpose" condition of critical parts, considering cleanliness, environmental conditions, packing protection, movement (rotation), shelf life, and rotables repair quality.

Process Measure **BOM (Bill of Material) linked to Materials Catalog**

The percentage of the items in the Equipment Register that have a Bill of Materials (BOM). Each BOM should be linked to the Materials Catalog (whether or not the materials and/or parts are stocked or direct purchased).

4.4.5 Measures for Reliability

Health Measure **Production Loss**

Quantity of Loss (in production units) attributed to equipment malfunction.

Health Measure **Condition Score (for Critical Equipment)**

This is a composite measure that summarizes the quantitative measures of the condition of critical assets. The "categories" that are measured are those that are universally found to be the chronic (or systematic) causes of equipment failure, for which a well-designed inspection program will address, and maintain records for preventive and predictive asset management. These categories of inspection and measure are:

- Lubrication (status, contamination, temperature),
- Cleanliness (product defects, wear rates, overheating of electrical and electronic equipment, cabinet air filtering, instrument air quality, HVAC and environmental standards),
- Vibration (balance, misalignment, looseness of fixtures and electrical terminations),
- Mechanical integrity (wall thickness, cracking, metallurgy, structural integrity).

These two Health Measures are "system" or global level measures for a plant or site. The reliability of individual items of equipment will be directly measured by a simple count of failure rate (frequency of occurrence, or hours of downtime).

Process Measure **Root Cause Analysis (Number per week)**

An immature organisation may only conduct a RCA occasionally – usually as a reaction to some catastrophic or tragic event. A proactive organisation will have many people trained in RCA, and have RCA as a way of life – that is, incorporated into the **daily** workflow of the work-teams. RCA will be conducted for any abnormal event (such as product defects, maintenance rework, equipment malfunction) that causes disruption greater than a predefined tolerance. Information generated is shared, and re-invested into reliability strategies, and operating procedures.

Process Measure **Condition-Based Risk Assessment (Yes/No, last review date)**

This is a process that requires an initial assessment, followed by periodic reviews of the condition of major assets, within the framework of consequence and likelihood of malfunction.
Various risk assessment techniques may be used, such as Criticality Assessment and RCM (Reliability Centered Maintenance).

4.4.6 Measures for Risk

Health Measure **Risk Index per Area (Trend)**

The "Risk Index" approach is described in Section 4.1 (Prime Objectives).

This same approach can be applied to plant or organisational areas in order to summarize the risks across all risk categories (People, Asset Productivity, Support Systems) for the area.

The aim is to provide a "forward view" of anticipated issues that need to be addressed so that the mission (asset effectiveness) can be delivered safely and dependably.

Process Measure **Active Risk Register (Yes/No, last active date)**

Risk Assessment and Risk Management are among the most important of activities. A mature organisation will have its risk register seamlessly incorporated into its works management process, and the works priority scale aligned to the risk ranking scale.
This measure audits the status of the outcomes of Risk Assessment.

4.5 Work Type

Process Measure **Work Type (Manhours)**

Studies have consistently demonstrated that both asset performance and cost effectiveness are strongly correlated with stable domains[2] (or modes) of organisational behaviour, namely: "Reactive", "Planned", "Proactive", and eventually after persistent transformational effort, "Best-in-Class".

A reliable indicator of organisational behaviour, which clearly differentiates the progression of capability from the Reactive to Best-in-Class, is the *type of work* which is conducted by the combination of engineering effort and in-field maintenance expertise.

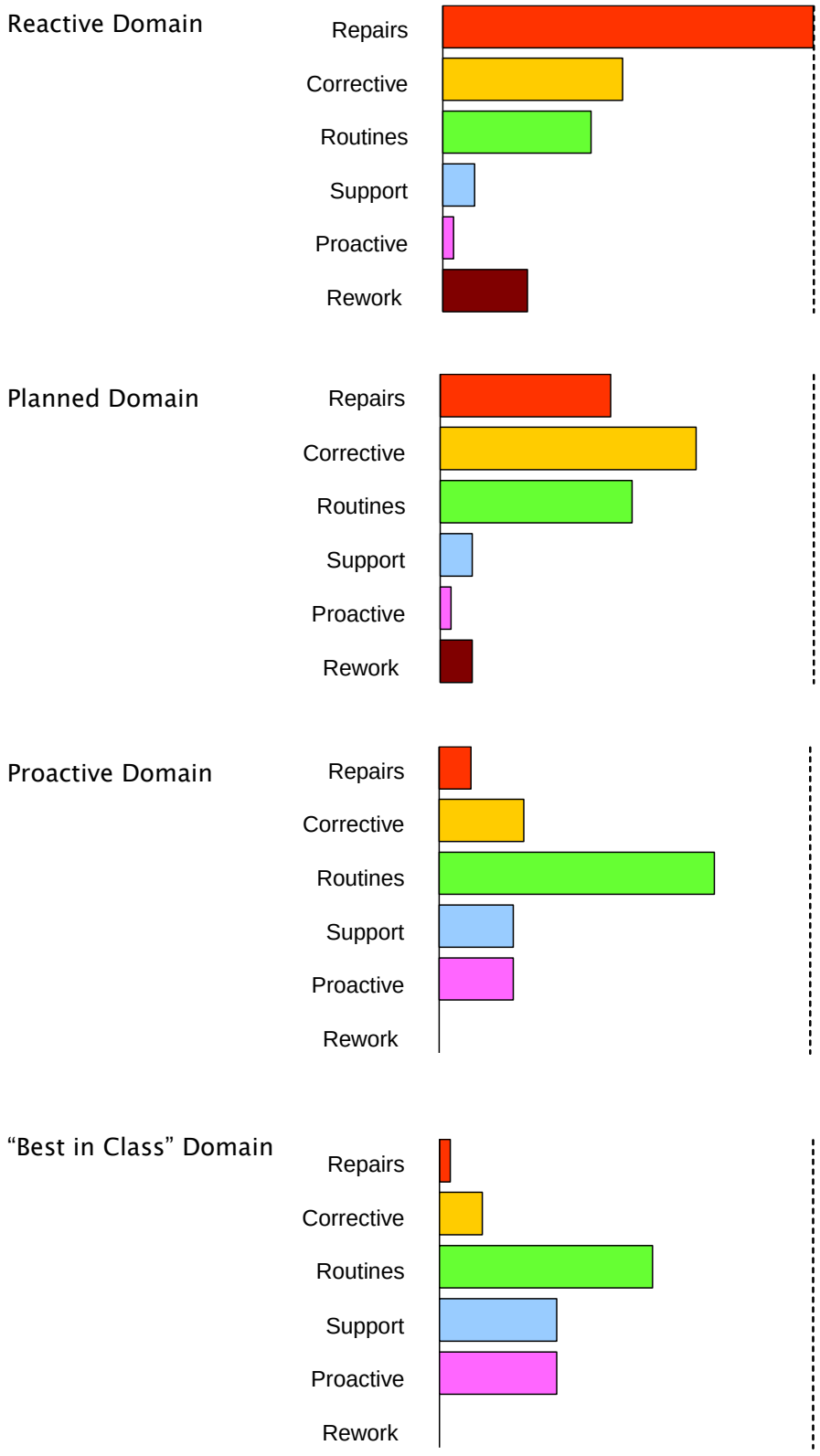
Measuring **Work Types** demonstrates behaviour, and provides important sign-posts for development of strategies enabling progression to the next superior mode. Typical categories of Work Type are:

- **Repairs** (defects, breakdowns, malfunctions)
- **Corrective** (planned activity, based upon outcome of the inspection program)
- **Routines** (applying reliability strategy through inspections and measurements, time and/or condition-based actions)
- **Proactive** (risk assessments and reliability projects – aimed at elimination of defects)
- **Rework** (very expensive quality non-conformance)
- **Production Support** (setups, product changeovers, regular assistance to operations)

[2] **Patrick Hudson** – *"Safety Management and Safety Culture - The Long, hard and Winding Road"*, First National Conference on Occupational Health and Safety Management Systems, Sydney 2000
Winston Ledet – *"Making the Move Toward a Learning Organisation – A Classic Journey of Change", 2002*

Shown below are typical distributions of maintenance work effort (as recorded in work orders), to demonstrate a progression of organisational maturity and competence, escalating through the improving modes of organisational behaviour:

Process Measures compared for different modes of behaviour:



APPENDIX A

Relationships between Asset Management Objectives.

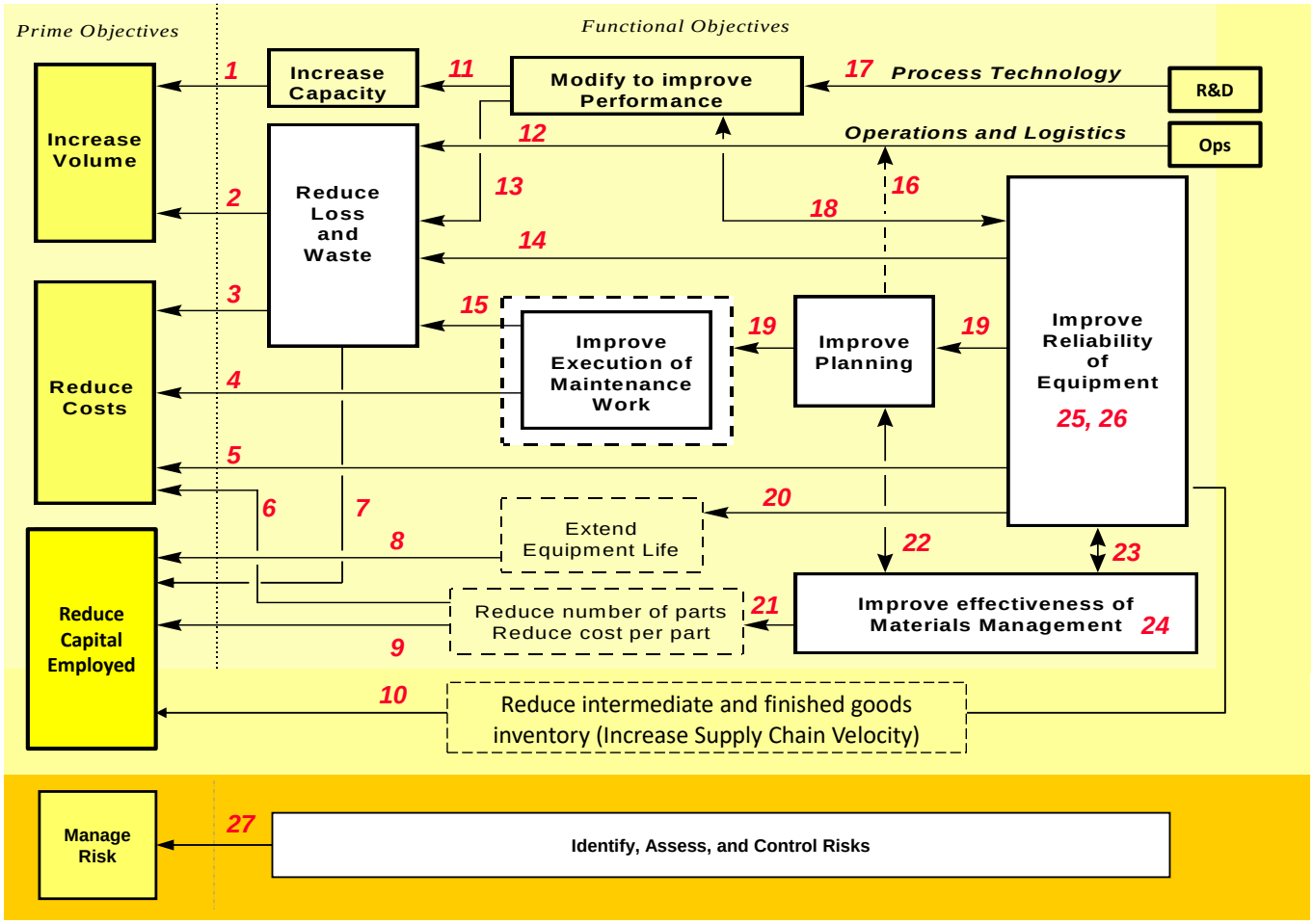
Return on Capital employed (ROCE) refers to a financial ratio that can be used to assess a company's profitability and capital efficiency. It shows how well a company is generating profits from its capital as it is put to use, and as such, provides a major metric for capital-intensive industrial facilities.

Formally, ROCE is defined as EBIT/CE, where EBIT is Earnings before Interest and Tax, and CE is Capital Employed (the amount of long- and short-term borrowings and equity required to sustain the facility). At the industrial plant level, however, the contribution to ROCE can be simplified by the proportional effects of ($V less $C) / $CE, where:

- $V is the value of production
- $C is the cost of production
- $CE is Capital Employed as defined above

Thus, the prime business objectives of the industrial facility, and accordingly for Asset Management, are to increase $V, and decrease $C and $CE, in addition to managing the Risk of operations.

In direct support of these *Prime Objectives*, a network of ***Functional Objectives*** can be defined for Asset Management activities (predominantly operational and maintenance functions) – as shown in the diagram below:



The following table describes the numbered relationships (or "influencing mechanisms") between the various objectives.

Relationships between Objectives

In Order to.....		*Actions.....*	*Influencing Mechanism (s)*
Increase Volume	**1**	*Increase Capacity*	*Increase size, power, efficiency.*
	2	*Reduce Loss & Waste*	*Reduce waiting time, over-processing, defects/rejects/rework, unnecessary motion.*
Reduce Direct Costs (fixed & variable)	**3**	*Reduce Loss & Waste*	*Reduce over-production, transportation, waiting time, over-processing, and unnecessary motion.*
	4	*Improve Maintenance efficiency & effectiveness*	*Less cost per activity - preparation, supervision, labour (and contractors) via planned and packaged work. Relevant skills deployed with precision.*
	5	*Improve Reliability of equipment*	*Less activity on equipment - maintain only what is needed, when it is needed.* *Reduce material/parts consumption.* *Remove redundant equipment. Eliminate chronic costs.*
	6	*Reduce cost per replacement part*	*Outcome of superior Materials Management (see below).*
Reduce Capital Employed	**7**	*Reduce Loss & Waste*	*Reduce transportation, and inventory of raw material, WIP, and finished goods.*
	8	*Reduce rate of capital investment, by extending equipment life*	*Obviate need to finance capital replacements, by optimizing utilization of existing assets (OEE).*
	9	*Reduce number of spare parts, cost per part, and cost of storing parts.*	*Reduce working capital required to finance storage costs. Remove redundant equipment and associated spare parts.*
	10	*Increase Supply Chain Velocity (aka DIO, Days of Inventory on Hand)*	*Improving reliability of processes in manufacturing chain reduces required quantity of intermediate and finished goods inventory.*
Increase Capacity	**11**	*Improve equipment performance by modification*	*Increase size, power, efficiency.* *Improve operability, ergonomics, maintenance techniques.*
Reduce Loss & Waste	**12**	*Supply issues, Customer Issues, Operating Issues.*	*Address manpower, materials, and methods – in the operating context.*
	13	*Improve equipment performance by modification*	*Improve efficiency, longevity, dependability, reduce variation.*
	14	*Improve Reliability of equipment*	*Less downtime - better longevity, and dependability. Reduce variation, energy consumption, Reduce opportunity for introduced defects (via repair, spare parts, operator adjustments).*

In Order to.....		*Actions.....*	*Influencing Mechanism (s)*
	15	*Improve Maintenance efficiency & effectiveness*	*Less downtime, rework.* *Right First Time, and faster handback.*
	16	*Improve Production and Maintenance scheduling*	*Schedule maintenance to coincide with production opportunities.* *Avoid unplanned (forced) shutdowns.*
Improve equipment performance by modification	***17***	*Improve Process Technology*	*Capital investment, and small scale operational and/or equipment improvements.*
	18	*Improve Reliability of equipment*	*Capital investment, and small scale operational and/or equipment improvements.*
Increase Planned and Scheduled work	***19***	*Improve Reliability of equipment*	*Dependable equipment allows greater confidence & predictability in planning & scheduling. Less incidence of breakdowns and injected work.*
	19	*Improve planning and scheduling skills*	*Not just for planners, but also for customers (field action groups) and beneficiaries (production).*
	22	*Improve Materials Management*	*Reservation, purchasing, delivery of materials to meet the plan of work.*
Improve Maintenance efficiency & effectiveness	***19***	*Increase planned and scheduled work*	*Better preparation for field work.* *Better use of contractors.* *Consistency of practices & procedures.*
	19	*Improve planning and scheduling skills*	*Better coordination and use of resources.*
	19	*Employ procedures, maintenance history, and CMMS*	*Availability of information - history, materials, procedures.* *Better knowledge base - do better next time.* *Consistency of practices & procedures.*
		Develop cooperative work teams	*Improve deployment of resources.* *Dispense with artificial demarcation - on shopfloor and amongst staff / management.*
		Match skills to needs	*Apply appropriate skills to tasks.* *Train accordingly.*
		More effective contracting	*Import contractor flexibilities, best practices and ideas.* *Transform fixed costs into variable costs.*
Extend equipment life	***20***	*Improve Reliability of equipment*	*Steady, predictable performance (reduced variation) reduces wear.* *Reduce breakdowns - reduces excessive wear.* *Reduce opportunity to inject defects.*

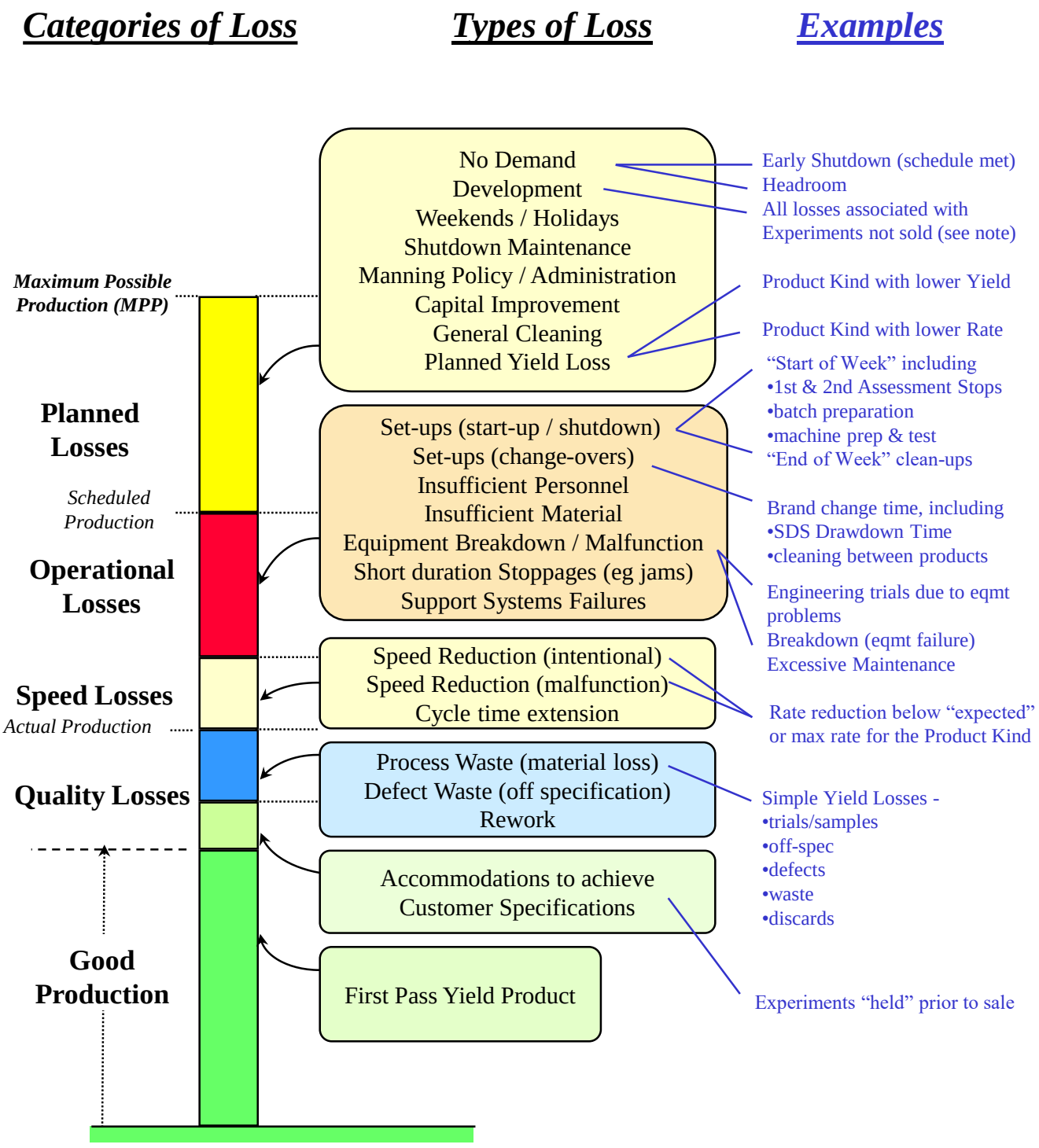
In Order to.....		*Actions.....*	*Influencing Mechanism (s)*
Reduce cost per part	***21***	*Improve Materials Management*	*Use CMMS & BOM's to aid purchasing practices.*
Reduce number of spare parts, cost per part, and cost of storing parts.	***21***	*Increase planned and scheduled work*	*Parts purchased according to a plan - i.e. when needed.*
	21	*Improve Materials Management*	*Rationalize stock holdings according to need.*
Improve Materials Management	***22***	*Synchronize with Maintenance Planning*	*Reservation, purchasing, delivery of materials to meet the plan of work.*
	23	*Employ procedures, maintenance history, and CMMS*	*Provide history of usage as a basis for rationalization.*
	23	*Life-cycle cost purchases*	*Minimize proliferation by short-sighted lowest cost policy.*
	23	*Eliminate obsolete parts*	*Reduce overheads. Simplify task.* *Focus on customer requirements.*
Improve Materials Management (cont'd)	***24***	*Reduce insurance stock*	*Risk assessment and clarification of policy.*
		Converge equipment types	*Risk assessment and clarification of policy.*
	24	*Form supplier alliances*	*Better use of capital, space, expertise.*
		Use supplier inventories	*Better use of capital, space, expertise.*
		Rationalize parts within and between sites	*Reduce overheads.* *Simplify task.* *Focus on customer requirements.*
Improve Reliability of equipment	***25***	*Eliminate the causes of equipment failure: malfunction, maloperation and imported defects*	*Vision and commitment.* *Management support for a High Reliability Organisation.*
Eliminate the causes of equipment failure: malfunction, maloperation and imported defects	***26***	*Review operating practices*	*Identify operating actions which introduce defects.* *Eliminate causes of defects, variations & inconsistencies.*
		Improve maintenance practices	*Identify maintenance actions which introduce defects.* *Eliminate causes of defects, variations & inconsistencies.*
		Restore equipment condition	*Must have and adequate description of "as new" - i.e. a specification.*
		Examine root-cause of failure	*Address problems, not symptoms.*

In Order to.....		*Actions.....*	*Influencing Mechanism (s)*
Eliminate the causes of equipment failure: malfunction, maloperation and imported defects (cont'd)	***26***	*Establish maintenance policy per equipment type / group.*	*Criticality review of failure modes.* *Decide on form of maintenance: - planned, preventive, predictive, breakdown.* *Identify and publicize reasons for doing the maintenance.* *Establish long range maintenance plans.*
Manage Risk	***27***	*Identify, Assess and Control Risks*	*Establish the governance plan that verifies Compliance to agreed risk mitigation tasks. Apply ongoing Due Diligence to review periodically that mitigation tasks are (a) relevant to current and future risks, and (b) effective in providing protection.*
			Apply consistent Risk Characterization across all disciplines.
			Deal with High-Consequence Failures ahead of all other risks when prioritizing risk mitigation tasks.
			A single administration system (such as Enterprise Asset Management, or CMMS) is far superior for verifying compliance than multiple risk registers in separate administration vehicles.

APPENDIX B

Examples of Loss Categories & Types

All Loss Quantities are expressed in Units of Production:



Note on Experiments:
If the product of an experiment is not intended for sale, all losses are deemed "Planned".
If the product of an experiment is intended for sale, then the production time is considered as normal operation, and losses are categorized under Operational, Speed or Quality. Product held for inspection / test / evaluation is classed as an Accommodation, but categorized as Good Product if passed for sale.