The Loss Prevention Imperative

Structuring industrial enterprises to prevent losses, and capture lost opportunity

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1 Abstract

When an industrial catastrophe occurs, the consequential losses can be profound, and our community's sense of justice requires that blame be legally assigned. It is the owner's obligation and duty of care to take every reasonably practicable precaution to prevent failure and harm.

When an industrial facility fails to meet expectations, financial loss can be crippling, and may manifest every operational day as lost opportunity, namely failure to perform to its potential.

This paper addresses the objective of *Loss Prevention* – preventing actual loss, and preventing the loss of expected benefit. The strategy for this *Loss Prevention Imperative* is the design of industrial resilience via the virtuous combination of Asset Performance Management (APM), High Reliability Organisation (HRO), and currently available Knowledge Management Technology (KMT). In this strategic conception, industrial performance is defined and measured by the *absence* of loss.

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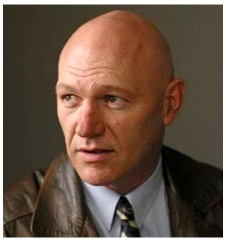
[1] About the Author:

Ian has over 35 years of international manufacturing and industrial engineering experience and is a recognised leader in asset management and reliability engineering. Ian has worked with major international companies including ExxonMobil, Kodak, Siemens and GE-Digital on asset capability, operational improvement, workforce engagement, and digital transformation. Ian now consults independently with Flagstaff Consulting Group.



2 Contents

List of Figures and Illustrations

3 EXECUTIVE SUMMARY

How do you visualize perfection ?

A perfect diamond ? Exquisite craftsmanship ? The perfect gymnastic routine ?

A practical measure of perfection is the degree of imperfection – that is, by counting the flaws or defects, and decrementing away from the state of *flawlessness*.

Industrial performance can also be measured in this way – by accounting for the amount of loss incurred against the reasonable expectations of flawless operation, from day to day.

The aim of the ***Loss Prevention Imperative*** is to aspire to flawless operation of industrial facilities. The objective is to prevent loss by (a) eliminating or mitigating conditions that may contribute to catastrophe, and (b) minimizing adverse events and chronic defects that generate both opportunity loss, and actual loss in operational performance.

The strategy for this ***Loss Prevention Imperative*** is the design of industrial resilience via the virtuous combination of High Reliability Organisation (HRO), and Asset Performance Management (APM). That is, when the resilient virtues of HRO are combined with the incisive technical discipline of APM, a paradigm-shifting synergy is created. This opportunity is the ability (a) to maximize the utilisation of industrial assets in a safe, practical and sustainable way, (b) to meet investment targets without extensive capital injection, and most importantly (c), to avoid, or safely recover from adverse events and/or catastrophes. This synthesis of technical precision and resilient virtues is achieved by designing a workplace culture that is constantly attentive to day-to-day actual and potential losses, and organisationally anxious about the presence of threats.

The scale and interconnectivity of 21st century industrial enterprises present owners with unprecedented challenges to identify and control operational risks. Fortunately, Knowledge Management Technology (KMT) has evolved to a level of sophistication whereby it can match the variety of detail in the physical space, both technically and chronologically. Therefore, to mobilise the synthesis of HRO and APM at this enterprise scale, a third ingredient is necessary – the smart, granular knowledge management embodied in currently available KMT.

The ***Loss Prevention Imperative*** is a practical and defendable application of due diligence in managing industrial facilities - an approach where knowledge of risks and ongoing losses can be recognised, shared, and cost-effectively controlled across the enterprise; where corporate knowledge is retained and enhanced in conditions of staff and technology turnover; and where operations may be conducted confidently across various regulatory jurisdictions.

3.1 Structure of this Document

The next section (4) describes why Loss Prevention is imperative, and why it is the objective of this White Paper.

The following section (5) introduces a generic description of large-scale 21st century industrial facilities, and the notion of resilience as an *organisationally designed outcome for the sustained focus upon Loss Prevention*.

Subsequent sections (6, 7, and 8) discuss three contributing disciplines, which are:

- APM - Asset Performance Management
- HRO - High Reliability Organisation
- KMT - Knowledge Management Technology

In this relationship, APM contributes the asset-focused design principles and methodology, HRO represents the organisational design for necessary human awareness (including its similarities with Lean Manufacturing principles), and KMT provides an enabling infrastructure for planning, execution and governance.

Finally, section 9 provides insights into the governance necessary for large and complex facilities, both to sustain acceptable performance, and to protect community and our environment from harm.

4 LOSS, and OPPORTUNITY LOSS

"Risk is generally divided into two broad types: pure risk (downside risk) and speculative risk (or upside risk)".[2] The consequences of downside and upside events are:

- Downside consequence is **"Loss"** – measured as harm to persons or environment, and/or adverse financial impact upon persons, property, project timing, or legal liability.
- Upside consequence is the desired outcome of an undertaking - the expected reward or the "value add". However, when the expected reward is not achieved, a "Loss" can be measured against that positive expectation. This loss of unfulfilled expectation is **"Opportunity Loss".**

4.1 Loss of Financial Reward

In the industrial setting, opportunity loss is directly translated into loss of expected financial reward. This is readily illustrated by the ubiquitous example of less-than-perfect reliability of physical assets, as follows.

It is axiomatic that reliable industrial facilities not only deliver capacity when required, but also provide flexibility in exploiting opportunities of supply and demand. *Reliability* therefore constitutes an essential element of industrial performance, *in confidently* delivering the intended functions with *sound, consistent character and quality*. Indeed, asset reliability can be mapped directly to financial performance via the factors that contribute to Return on Capital Employed (ROCE)[3]. With reference to Figure 1:

- Improving plant reliability reduces losses, thereby materially contributing to ROCE by optimizing the utilization of existing capacity, without adding new capital.
- Better reliability means fewer breakdowns, which reduces fixed costs, and reduces the variable costs of energy, process disruption, and rework.
- Improving reliability enables equipment life to be extended, which allows for a reduction in the rate of capital investment. Capital Employed is further reduced, as better reliability enables a reduction in spare parts (capital invested with zero return).

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[2] Robinson, R and Francis, G, *"Engineering Due Diligence, 11th Edition"*, (R2a, 2019)

[3] ROCE (Return on Capital Employed) is defined as the ratio of Earnings (after tax) to Capital Employed (which is the sum of borrowings and shareholders' equity), and is a prime indicator of whether the business is achieving targeted earnings and returns for shareholders' investment.

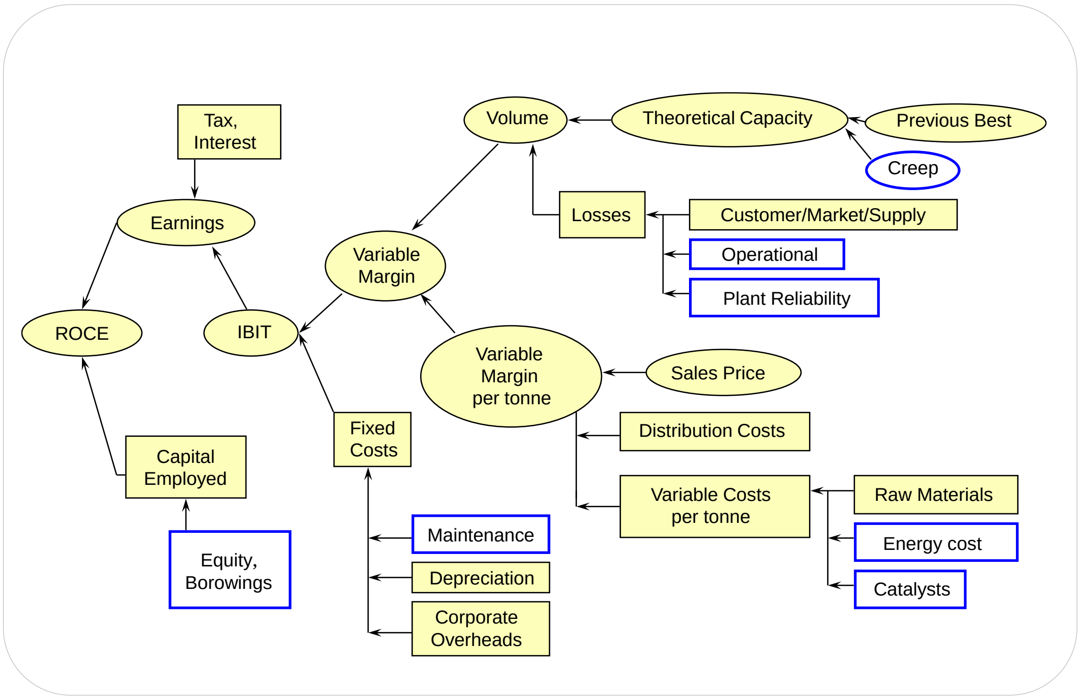

Figure 1 ROCE for an Industrial Facility

Another often-overlooked benefit is gained when plant reliability is improved. That is, **intermediate product inventory** can be confidently reduced if the reliability of assets in series can be simultaneously raised. This is true not only for plant assets within a facility, but also for facilities in series along the supply chain. Thus, a further powerful positive effect on ROCE emerges, when the amount of product inventory is reduced.

Finally, plant reliability beneficially affects the order-to-cash cycle by reducing the waves of instability generated by variations in plant behaviour, as mentioned in section 5.1.

4.2 Loss as Imperfection

Threats to the "value add" materialize as losses during the facility's life through two types of phenomena:

1. Singular events such as a catastrophe, or many single and many recurring events of smaller consequence.

2. Chronic continual losses manifest as conditions such as unanticipated bottlenecks, physical deterioration, breakdowns, increasing asset complexity, erroneous operation, and inefficiencies and/or delays in administration, manning, logistics, maintenance, operations, and material delivery.

On closer examination, the second phenomenon is just a chronic case of the first, where the consequences of events are stretched in duration to become long-standing "conditions". These conditions often come to be regarded as normal operation, the accepted state, or the accepted level of performance.

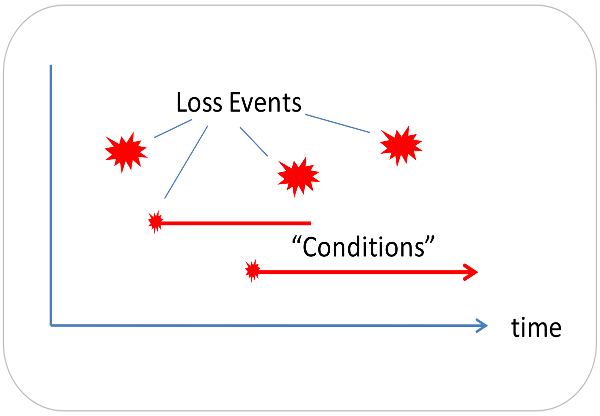

Figure 2 Events and Conditions

For example, a tyre puncture in a racing-car is clearly a singular event that may lead to losing the race. However, the incorrect tyre inflation pressure is a condition that over the duration of the race, leads to poor handling and loss of position. Furthermore, there will be reasons (or root causes) as to why the incorrect condition has arisen.

Whilst events and conditions may feed each other in a web of cause-effect relationships, the approach for reducing Loss must consider both types of phenomena (singular events, and prevailing conditions).

4.2.1 Using Loss to Measure Industrial Performance

In an ideal world, industrial facilities would perform perfectly to match opportunities, deliver the required outcomes, and meet the expected Return-On-Investment (ROI). Anything short of this expectation is a Loss.

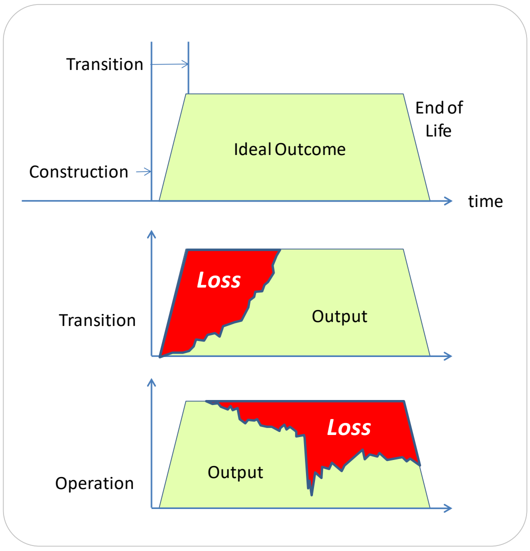

Figure 3 Losses from Ideal Performance

The performance of a facility may be measured by the magnitude of the losses incurred, when compared against the ideal outcomes that could have been accumulated over the desired time-period.

For example, an industrial plant's lifecycle consists of construction, transition, operation, and dismantling.

Ideal performance would be illustrated in Figure 3, with no losses to the ideal (**flawless**) outcome.

However, if the transition to operation does not go well, or if subsequent operation does not meet expectations, then large losses are incurred that have a significant impact upon the ROI.

Furthermore, if *the expectation of ideal performance is discounted due to the explicit or implicit acceptance of adverse conditions, or lack of awareness of same,* then the loss experienced is entirely **Opportunity Loss**.

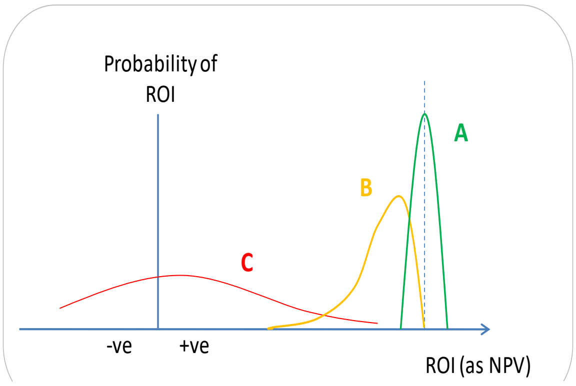

Figure 4 Impact of Loss on ROI

Figure 4 illustrates the financial effect of poor transition (B), and poor operation (C) upon the expected reward (ROI).

Under no-loss conditions (A) there is a high confidence of achieving the targeted ROI.

4.3 The Loss Prevention Imperative

The **objective of the Loss Prevention Imperative** is to maximize the productive capacity of installed industrial assets (leading to financial reward), whilst simultaneously minimizing the likelihood of recurring losses and catastrophic events of any sort.

The **conceptual framework** to address this objective is the representation of downside risk and upside risk onto a single risk-continuum with "loss" and "opportunity loss" on the same consequence scale. In this way, the magnitude of actual and potential loss can be readily aligned to the consequence dimension of the many risk analysis techniques used within enterprises, thereby providing a common valuation for resolution of cross-functional priorities.

The **strategy for implementing the Loss Prevention Imperative** involves designing a working environment that encourages knowledge and awareness of potential losses, hazards, and threats to operations – thereby being responsive to both downside and upside risk. Such a working environment will be described herein as **resilient**.

Local experts should specify the difference between normal and abnormal conditions, so that the presence of loss and opportunity loss may be *recognized and anticipated*. Practicality emerges from the real-time participation (i.e. daily) of the people who are closest to ongoing operation of the facilities. In particular, the strategy must enable human beings to recognize threats as they occur, and to act as soon as practicable to avoid losses and minimize risks, with knowledge, anticipation, and preparation.

5 INDUSTRIAL RESILIENCE

Operational performance is systematically improved by reducing the likelihood of loss, as well as the incidence of actual loss (including Opportunity Loss). This section 5 provides context for the application of mutually supportive strategies for implementing the Loss Prevention Imperative, namely APM (section 6), HRO (section 7), and KMT (section 8).

5.1 A Model for Resilient Industrial Assets

Whether an enterprise works for profit or for public benefit, the purpose of their physical assets is to affect a *transformation* to create or add value. The condition, performance and resilience of these physical assets have a profound influence upon the performance of the business.

Figure 5 Instability in the Order-to-Cash cycle

Instability and/or disruptions suffered by the physical assets create waves of variation upstream and downstream in the order-to-cash cycle. This variation manifests as additional inventory, processing, and procedural waste, not only adding to variable and fixed costs, but also adding to the working capital needed to support the business.

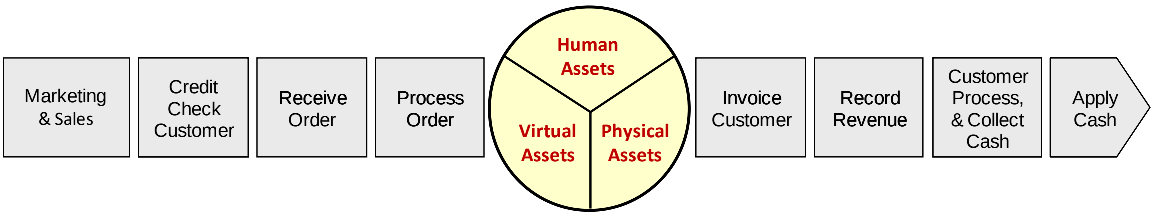

Figure 6 Dependable and resilient physical asset systems

When condition and performance of the physical asset system is stable, then the business is able to operate in a much “leaner” state overall. Indeed, smooth and reliable operation of physical assets has a powerful influence upon financial outcomes such as ROCE (per section 4.1).

5.1.1 Consider Industrial Assets as Living Creatures

Is the following definition of an industrial asset sufficient ?

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

Such material definitions as above are manifestly inadequate in describing the complex, interrelated, and constantly changing *functionality* of large-scale industrial systems of the 21st century. Today's facilities are required to interact, grow, adapt, and often evolve over many generations of technology.

Terminology such as "asset health" and "asset lifecycle" are now common practice among engineers, *yet the biological metaphor can be extended to gain a more profound insight*.

A far more useful definition of large-scale industrial systems is provided by the Model of an Operating Asset,[4] which applies from the first conception of purpose to the final disposal of the assets.

In this model, the *asset system* consists of the interdependent and evolving combination of:

- the **physical assets**,
- the **virtual assets** - knowledge embedded in artefacts and software (models, procedures, visualizations) describing the physical assets, and
- the **human assets** - people operating and maintaining the physical assets.

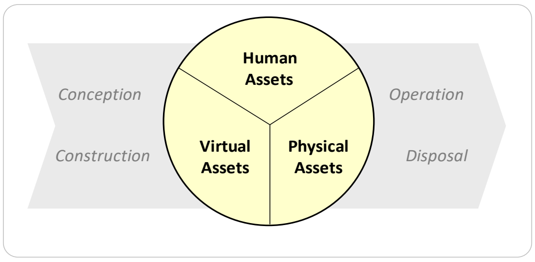

Figure 7 Model of an Operating Asset

Today's industrial asset systems are so large and complex that people rely on the accuracy of virtual assets to interpret and control the daily behaviour of physical assets. In this regard, *it is critical that the information flowing between the three aspects is always synchronized, to enable the asset system to operate with resilience*. Indeed, this synchronization invokes the biological virtues of integrity, endurance, and resilience.

The Virtual Assets are particularly critical for major issues such as:

- Catastrophic internal or external events (avoidance / mitigation / recovery).
- Milestone transitions from construction to operation to commissioning, and for subsequent modifications and/or major maintenance projects.
- High turnover of operating staff, where corporate knowledge is the binding agent.

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[4] Snitkin.S, *Asset Lifecycle Management*, (ARC Advisory Group White Paper, May 2009)

5.2 Dealing with Disappointing Performance

On many occasions during the operating life of industrial assets, owners experience disappointment with productivity and/or deteriorating performance. The causes are widespread and numerous, and owners may be persuaded to either downgrade their expectations, or inject new capital to recover productivity or capacity, or expand capacity.

An alternative strategy is to *optimize the productivity of existing assets* by focusing resources into Gap 1 of Figure 8 below, which represents the current state of **Lost Opportunity**.

In Figure 8, the evolving performance of a large facility (such as a petrochemical plant) may be conceptually represented by an "experience curve", which implies that capacity should improve over time through human learning and application of smart technology. In this illustration, the existing level of performance is represented by the green bar at level C.

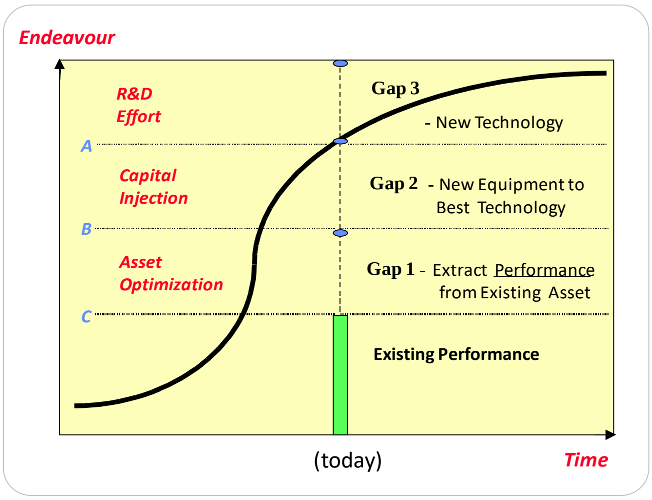

Figure 8 Asset Capacity Experience Curve

For existing (brownfield) facilities, the ideal performance would be at level B – the best that could be achieved with existing assets and operating personnel.

For new (green field) facilities, or for upgrading existing assets, the ideal performance would be at level A, taking advantage of the best currently available technology.

By mobilising techniques designed to systematically address causes of production loss (Gap 1), and *designing methodology* that shifts the mindset of people, hidden capacity that is otherwise unavailable can be liberated and set to work.

Furthermore, if additional capacity is required, then it behoves owners to reduce Gap 1 prior to injecting new capital, otherwise the existing Gap 1 ratio (C/B) will continue to prevail in the upgraded scenario. Owners with multiple facilities may use this argument to preferentially allocate new capital to sites with better asset productivity.

5.3 Responding with Resilience

The task of unlocking latent capacity (preventing Gap 1 losses) is multi-dimensional and relentless, in that it applies for each and every day of the facility's operational life.

It may seem simple, but the task is fundamentally expressed as the double-sided proposition: *"to achieve the objectives whilst avoiding the losses"*. A resilient enterprise will give nearly equal attention to both sides of this proposition, whereas enterprises with low asset utilisation (Gap 1) usually have poorly developed plans to address the daily parade of loss events and chronic small losses.

In simple terms, a resilient enterprise will need three vital ingredients:

1. capable and dependable assets, work-processes, and people,
2. active loss prevention strategies that constantly stimulate people, by prompting individual awareness, anticipation of risk, and minimization of ongoing losses, and
3. "clarity of purpose" that pervades all corners of the enterprise, engendering quality relationships and confidence in the leadership.

5.4 Designing Resilience into Industrial Assets

The concept of "Resilience Engineering" emerged in 2006[5] within the context of safety, and is described therein as *"a paradigm for safety management that focuses on how to help people cope with the complexity under pressure to achieve success"*. This reference defines resilience as follows:

> *"Resilience is the ability of an organisation (system) to keep, or to recover quickly to, a stable state, allowing it to continue operations during or after a major mishap or in the presence of continuous significant stress."*

This paper argues that this powerful paradigm is not limited to safety management, but also applies to the management of large and complex industrial systems (and perhaps to any management scenario where risks impinge upon objectives).

Whilst "resilience" has not yet been specifically defined or measured for industrial systems, it is nevertheless a characteristic or *virtue* that is displayed by organisations that adopt clearly defined and proven approaches for managing their facilities.

A strategy to deliver resilient industrial systems may be succinctly described by two conceptual approaches that are mutually supportive and ultimately necessary for sustainability. The two concepts are: (1) Asset Performance Management, and (2) High Reliability Organisation. A third (supporting) element is also necessary for sustainability, which is (3) smart granular Knowledge Management Technology, which is now widely available.

[5] Hollnagel, Woods & Leveson, *Resilience Engineering Concepts and Precepts* (Ashgate, 2006)

These three elements are summarized here, and described in more detail in the following sections.

Asset Performance Management (APM) is:

- **in the shortest time-period:** measuring "performance", and rapidly adjusting activities to meet the hierarchy of enterprise objectives.
- **over the long time-period:** controlling risks of operation, anticipating changes in condition and performance, and diligently applying loss prevention strategies within the agreed long-range budget.

High Reliability Organisations (HRO) are:

- organisations that, despite operating in conditions of high potential for error and losses, are able to avoid losses most of the time. If losses occur, HRO's are resilient in containing losses and recovering operational capability.
- An attitude of "mindfulness" towards anticipation of hazards and failures pervades all levels of the HRO, leading to proactive attention to all manner of conditions leading to **loss, waste, and potential catastrophic events.**

Smart, granular Knowledge Management Technology (KMT) is:

- smart, cost-effective technology, now available to cater for the detail required to manage large and complex industrial facilities.
- enterprise-scale integration, critical for martialling massive volumes of information that enables human appreciation of condition, performance, and risk.
- enabling APM and HRO strategies to be deployed and monitored in near real-time.

6 ASSET PERFORMANCE MANAGEMENT

Industrial assets are built to generate wealth, and are expected to *perform* their intended functions whenever called upon during their lifetime. A short description of **outcomes expected from APM** is as follows:

Asset Performance Management (APM) aims to assure that an (industrial) asset safely performs its intended function over the time-period required. APM consists of:

- *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, maintenance, and technical support (product and process).*
- *controlling the risks of operating those assets over time. This requires careful assessment of performance and risk, and the projection of dependable operation over the longer time-period. Risk mitigation strategies manifest as standard operating procedures, and preventive maintenance procedures.*

This section extends the concept of "asset performance" as a technical basis for the coherent multi-layered management of large and complex industrial facilities.

6.1 The Objective of APM: Sustained Performance

In the clamour to provide APM software and services, vendors have created a wide variety of interpretations, thus muddying the conceptual landscape. This section presents a precise description of *the performance of a large and complex facility (or whole of enterprise), rather than the application of software and technology at the equipment level.*

"**Asset Performance**" is a measurable, enterprise-level characteristic of industrial facilities. Its essence is the **absence of loss**, as measured downwards from the ideal or flawless standard of production performance (where nothing fails).

"**Asset Performance Management**" (APM) is the coordination of disciplines that focus attention on optimizing the performance of existing facilities, by any viable means that reduces ongoing losses, and mitigates risks of adverse events.

So, the operational component of business strategy that addresses the performance of large and complex facilities would take the following form:

Objective	Optimize utilization of existing capacity
Measure (of Objective)	Asset Performance (expressed as trending Losses)
Strategy (to achieve Objective)	Eliminate chronic losses and risks to asset integrity

6.1.1 *Timing of Performance Measurement*

There are many dimensions in which to measure 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 has no chance of influencing activities in week 2 of that month.

Any practical attempt to manage performance must therefore be capable of observing, identifying, and measuring the relevant issues in near real-time. This obviously means instrumentation for automated machinery (nothing new), but also a heightened state of awareness for people at the frontline of asset operations, with the *confidence and support to act immediately on observation of actual losses, or anticipation of potential losses.*

6.2 Performance via Loss Prevention

In the context of APM, *Production Loss (in units of production)* is the yardstick, and focus of attention for optimizing the performance of large-scale facilities, whilst simultaneously addressing incidents of chronic loss, risk of catastrophe, and risks that threaten "license to operate".

To focus organisational attention on *loss prevention*, vital knowledge needs to be gathered and applied. In particular:

- A specification for the ideal state of operation, or condition, or level of performance, including a practical means of measuring the overall effectiveness of the actions applied. This is provided by a direct measurement of production losses as they occur (within predefined categories). *See 6.2.1*
- A concise description of the barriers that have been chosen to prevent or mitigate loss. These may take the form of engineering solutions, operational procedures, maintenance practices, contingency plans, and disaster recovery plans. *See 6.2.2*
- A structure for engaging the workforce in "anticipation and proactivity" so that understanding of purpose, and magnitude of consequences is communicated. Also, to encourage valuable feedback for preventive or remedial action. *See 6.2.3*

Furthermore, subject-matter experts and staff can extend loss elimination by:

- In-depth analysis of threats to the ideal state, and their consequence. That is, examination of the vulnerability of facilities to "high consequences of asset failure". In particular, gathering the knowledge of what things might fail, and how they might fail, so that better control options can be evaluated and applied [6].

- Knowledge of the characteristics that indicate "health" of the asset. That is, the knowledge to activate practical monitoring of threats, to observe the onset of degradation, and to collect evidence of behaviour. In this way, a framework for the anticipation of hazards, failures, and loss reduction is established, and preparation for remedy is planned.

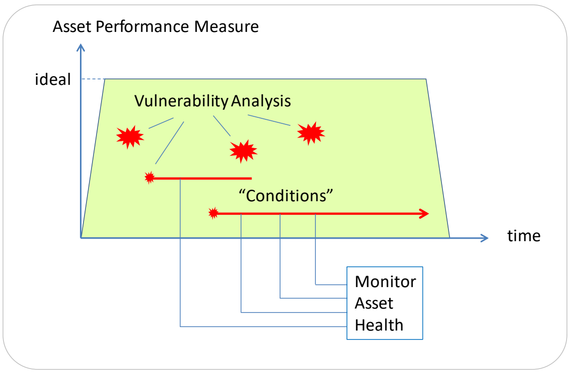

Figure 9 Asset Health Monitoring

6.2.1 Practical Measurement of Losses

A generic system for measuring manufacturing performance in green-field and brown-field facilities (and for capital upgrades), can be constructed using the principle of categorizing and measuring losses against an ideal marker, as illustrated in Figure 10.

Specifically, "ideal" means the maximum amount of production per chosen time-period, that the production facility could achieve, if it operated perfectly without quality defects, mishaps, or equipment failures. A practical value for this marker may be established by benchmarking, or by statistical means, providing that a realistic aspirational goal is agreed by stakeholders.

See footnote for practical determination of "Ideal" Marker[7].

In any case, the marker may be upgraded over time, where the adjustment effectively represents a measure of long-term continuous improvement.

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[6] The reliability engineering disciplines of FMECA (failure modes effects and criticality analysis), and RCM (reliability centred maintenance) are specifically designed to address this issue.

[7] Ideal Marker (i.e. 100% point of chart) = MDR x (Time Period of Interest), where:

- Maximum Demonstrated Rate (MDR) is defined as the maximum rate of production of first pass / first quality product that a unit has ever sustained <u>for a short time-period</u>
- A "short time-period" depends on the type of process, for example:
  - in a batch process - the time taken to produce a single batch
  - in a continuous process - a 24-hour period
  - in a complex multi-unit process – 5 days (or 7 days)
- The maximum rate of production is achieved with the <u>fastest</u> grade of product running perfectly, with no losses or rate limits.
  - MDR should be related to the best achieved (i.e. <u>demonstrated</u>)
  - MDR is <u>not</u> a long-term average
  - MDR will be determined by the process bottleneck

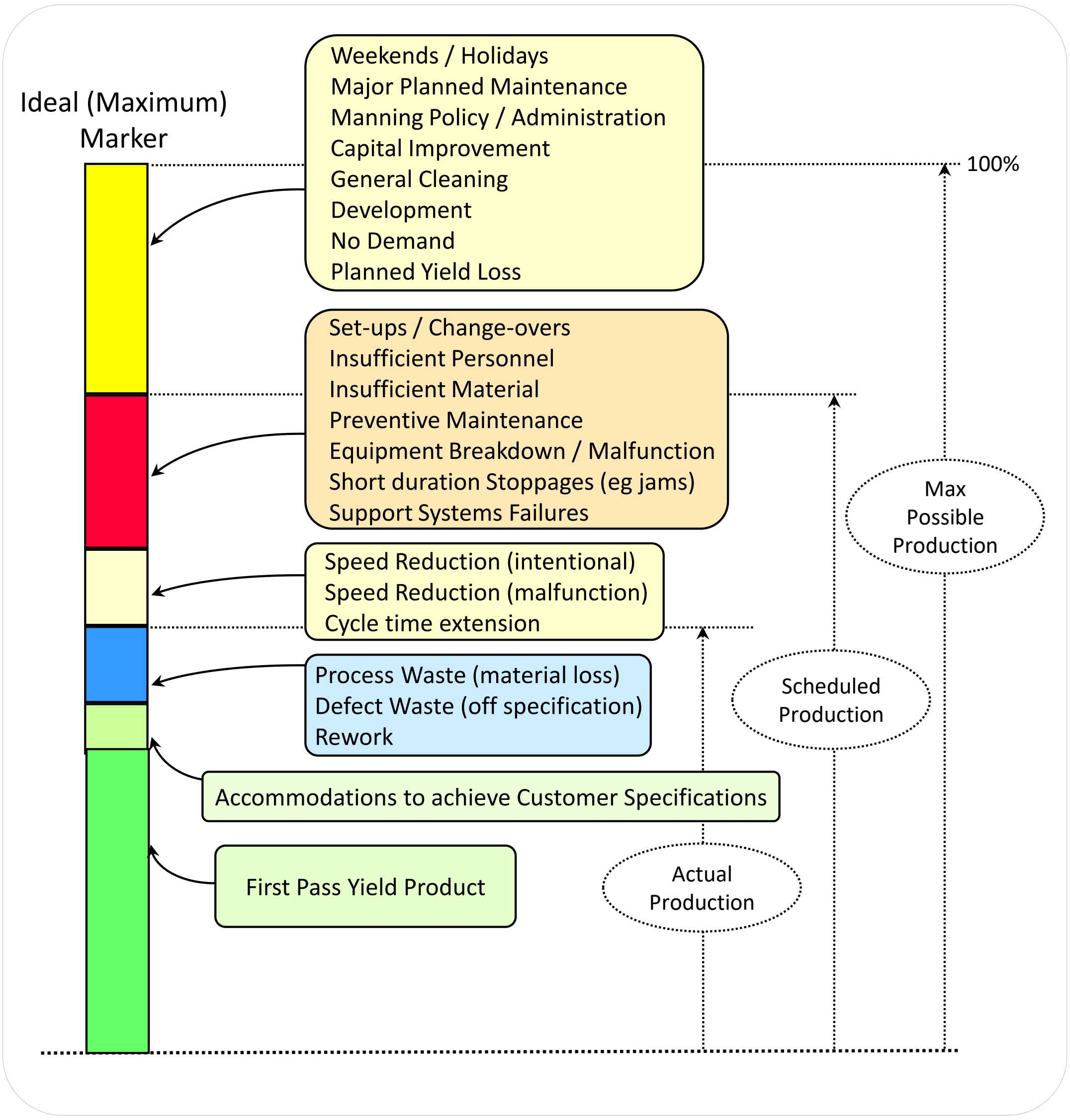


Figure 10 Categories of Loss (in Manufacturing)

The units of loss are the same as the units that are used for production. In the example of Figure 10, the units are "production quantity".

The value of this approach lies in observing, categorizing, and recording losses as they occur (in the short time-period) so that an accumulating pattern may be observed over time. This enables budgets and targets to be established within the loss categories.

Figure 11 shows how loss records per period may be strung together to create a run-chart. The frequency of measure may be any duration of relevance to the business unit (e.g. daily, weekly, monthly). However, the higher the frequency of measure, the more useful the data for two important reasons:

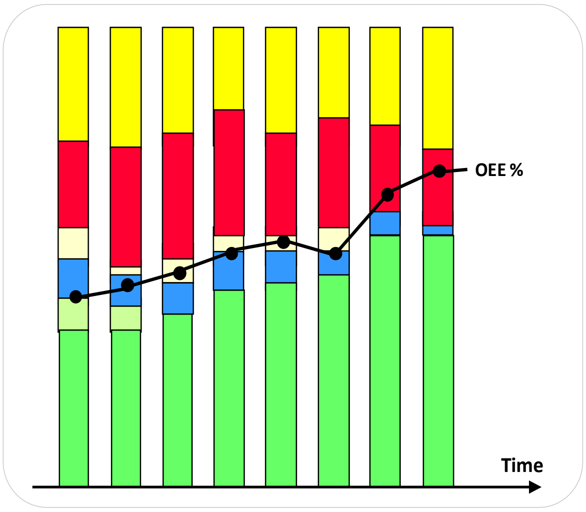


Figure 11 Loss per Measurement Period

1. Loss events may be more readily correlated with other conditions or events during the same measurement slice, thereby simplifying the analysis task.

2. The loss data can be fed back quickly to the people who are in position to influence the situation (by reducing or mitigating the loss). This also provides valuable education and training for operations, maintenance, and logistics personnel.

6.2.2 Barriers to Prevent Loss

Fundamentally, there are two approaches for loss prevention in industrial facilities, both of which are necessary for competitive performance:

1. **Top-down:** guided by risk management methodologies, focusing upon the high-consequence failures of equipment, operational and maintenance procedures, and associated human activity.

2. **Bottom-up:** guided by best-practice and quality principles, where quality of production depends upon sound equipment condition and the elimination of variation in the production process and equipment.

6.2.2.1 Top-Down Approach

The Reliability Engineering discipline provides many methodologies for analysing mechanisms of asset failure and associated risk abatement. One such methodology is described here: the "Bow Tie Model" which provides a practical method for deriving barriers that prevent and/or mitigate loss as illustrated in Figure 12 below.

The Bow Tie model (aka Threat Barrier Diagram[8]) may be applied to any situation leading to losses of any type (financial, reputation, market credibility, production quality, quantity, or harm to people and/or environment). The ultimate loss may be singular and catastrophic, or it may be continuous and cumulative (such as a prevailing poor condition or degradation, or events within any of the categories of loss illustrated in Figure 10).

[8] Robinson, R and Francis, G. *"Engineering Due Diligence, 11th Edition"*, (R2a, 2019)

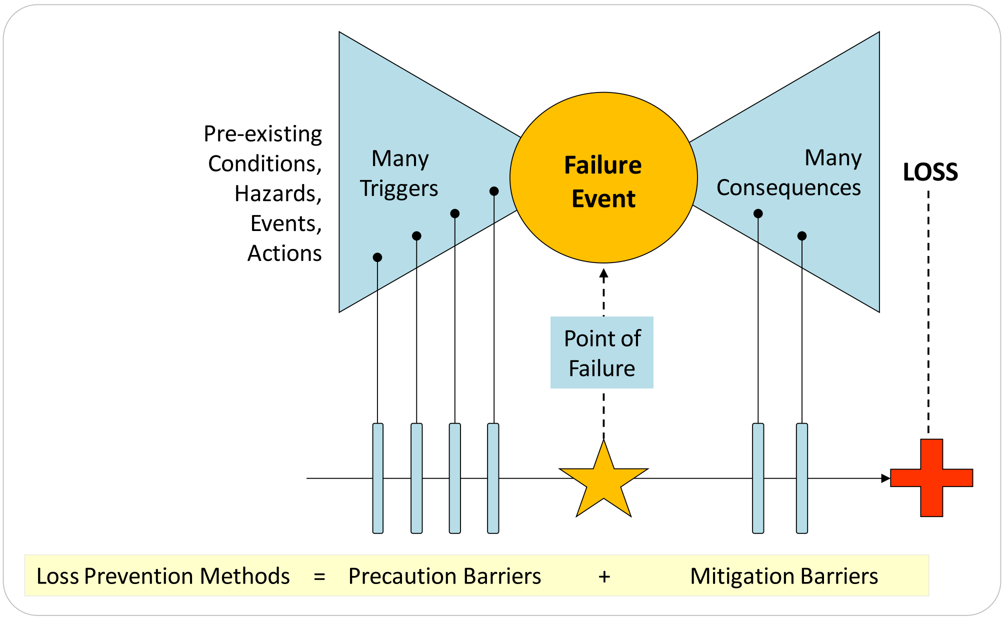


Figure 12 Bow Tie Model

The power of this model is the visualization of the mechanisms of failure, from threats (or hazards) to consequences. In this sense, it provides a user-friendly framework for analysis and understanding of risks, and the proactive disposition to anticipate threats and put countermeasures in place, thereby laying the groundwork for *resilience*.

The Bow Tie Model provides a practical cross-disciplined approach for developing strategies for *loss prevention*, as well as demonstrating ***due diligence*** in the common law duty of care, which is that:

> *"those who have control of any situation must demonstrate that all reasonable practicable precautions are in place for all foreseeable credible critical risks…".*[9]

Selection of the barriers to prevent or reduce the loss is guided firstly by a chronology of control (where action to prevent a failure is cheaper and more effective than recovery after the failure), and secondly, by an "hierarchy of control" that establishes the order of preference for technical solutions, tempered by the practicability and cost (Figure 13).

Effective strategies for *Loss Prevention* direct attention to the triggers (threats) of failure and the pathways to consequential loss, and constitute pragmatic and defendable applications of resources. Putting this methodology into practice means:

- Firstly, drawing attention to vulnerabilities that matter most – conditions that may generate the greatest loss (highest consequence-of-failure). This requires risk analysis conducted with subject matter experts and local participants, where the triggers of failure events, and their consequences are identified, validated, and prioritized. Thus,

[9] Robinson, R and Francis, G. *"Engineering Due Diligence, 11th Edition"*, (R2a, 2019)

the Bow Tie Model is an example of methodology that provides a mapping of credible events and pathways to failure and loss.

- Secondly, the strategies must have actions in place (the barriers) that are justifiable and cost-effective. That is, specifying (a) what to do and when, (b) what and where to observe the onset of deterioration, and (c) where to collect evidence of behaviour that indicates a threat, or sub-optimal performance. These may take the form of maintenance checks, instrumented condition monitoring, regular manual measurements, and recording and categorizing daily operational losses (as in Figure 10). In this regard, the tacit local knowledge of operations and maintenance personnel is invaluable when combined with engineering methodology brought to bear through the hierarchy of control.
- Thirdly, there must be evidence to determine whether the strategies are effective. This evidence is provided by the accumulating record of losses by category. An effective strategy will produce reductions in the targeted categories of loss, and/or frequency of adverse events (as measured per Section 6.2.1)

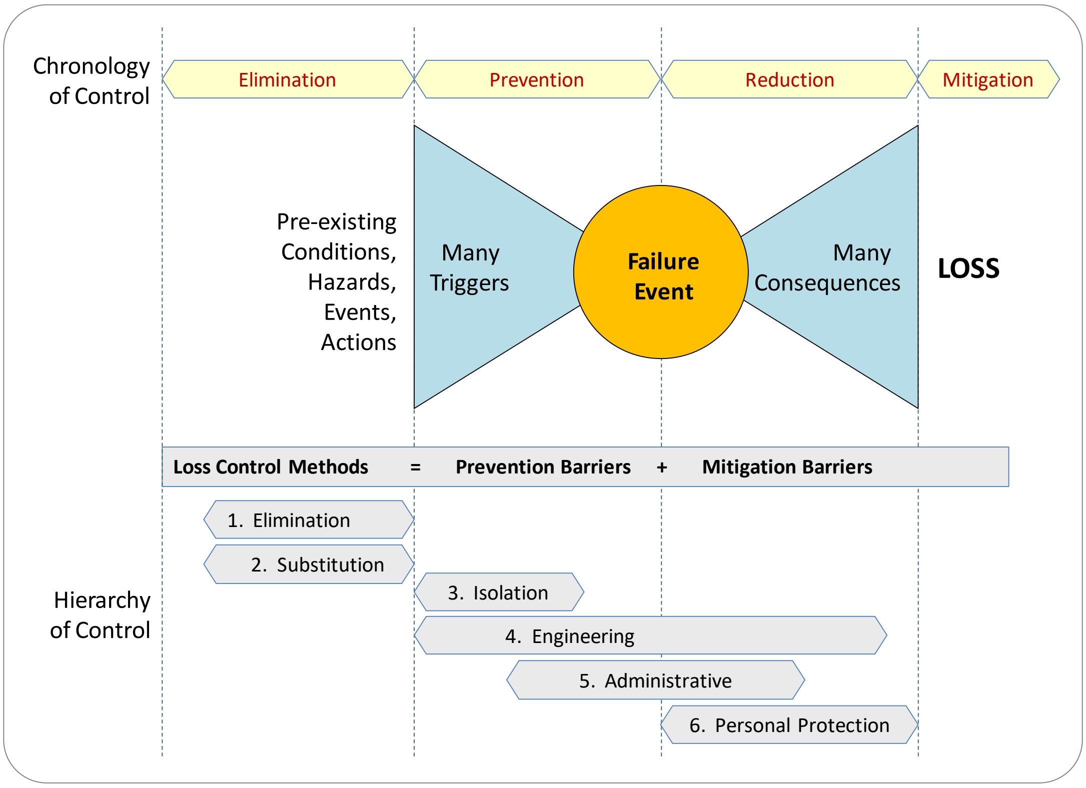


Figure 13 Application of Hierarchy of Control

6.2.2.2 Bottom-Up Approach

This approach is exemplified by TPM (Total Productive Maintenance)[10], which emerged as a vital component of the Lean Manufacturing movement. TPM and Lean are comprehensive, rigorous, and highly evolved methodologies, which have become best-practice in the industrial world. The underlying philosophy is for operations staff to eliminate equipment defects (within their control), so that sound equipment conditions prevail, thus enabling continuous and sustainable production improvements.

This approach does not rely on post-event analysis of equipment failure to justify high-quality maintenance practice. Rather, standards of cleanliness and performance are established as foundational requirements, and as a matter of common-sense and pride of ownership.

For example, engineering design, and subsequent maintenance instructions cannot anticipate the effect of **accelerated deterioration** caused by ignorance or neglect of the widespread root causes of equipment failure, namely:

Looseness	Looseness of fastenings or misalignment leads to vibration and subsequent mechanical deterioration of both mechanical and electrical components.
Lubrication	Lubricant is the sacrificial wear element in rotating machines. If lubrication is incorrect, incomplete, or ignored, then failure of expensive parts is inevitable.
Contamination	Contamination in moving parts accelerates deterioration. Contamination (or accumulation of dirt/dust) can also cause overheating failure in electronics.
Human abuse	Incorrect operational and/or maintenance procedures, for any reason, may cause just as much damage as neglect, ignorance, or wilful abuse of equipment.

Awareness of, and remedy for these conditions is the bedrock of *Loss Prevention*, and is a vital responsibility for the workforce that is charged with operating and maintaining complex industrial facilities.

6.2.3 Engaging the Workforce

It is critical that the knowledge of equipment behaviour gained by developing and deploying Loss Prevention strategies is perpetuated in corporate memory.

This knowledge is made explicit by specifying the *expected condition and performance* of subsystems and equipment that make up the facility. Only then can the *actual condition and performance* be recorded and compared with *expected* (Figure 14) to determine whether the situation is deteriorating, and whether the prevention and mitigation activities are effective in maintaining the barriers to loss.

[10] Suzuki, Tokutaro, "*TPM in Process Industries*" Productivity Press, 1994

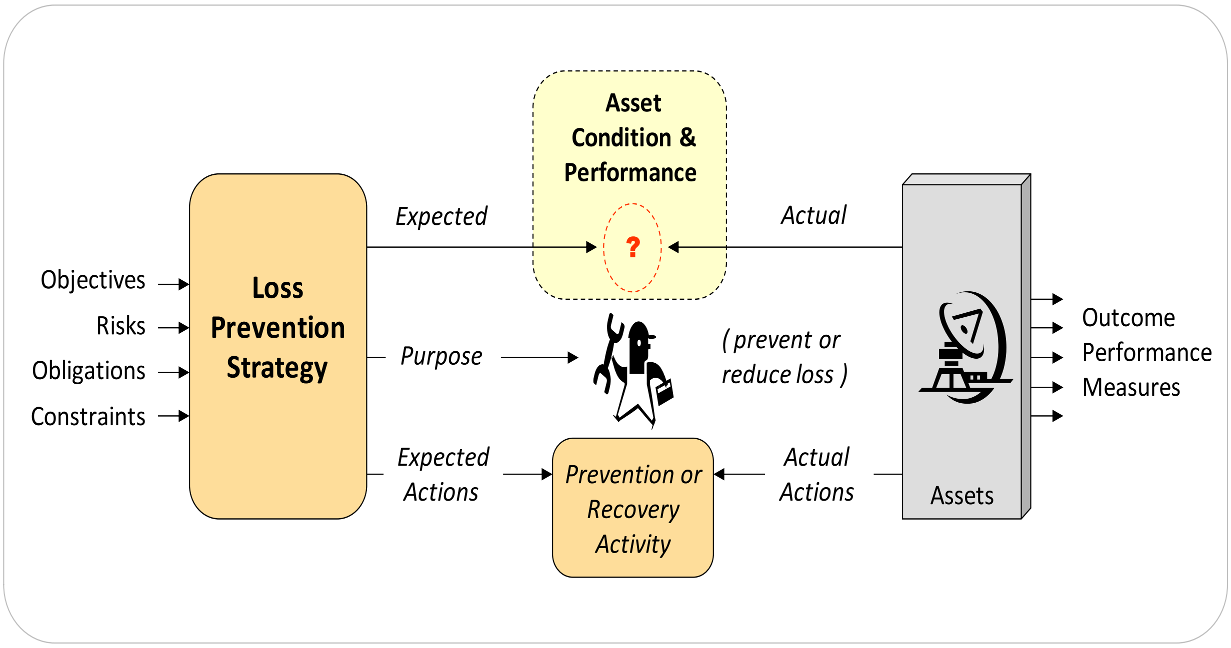


Figure 14 Practical Deployment of Loss Prevention Strategy

Strategies for *Loss Prevention* must be technically astute, and be accepted as valid by those that are employed to carry out the tasks. In this regard, the active involvement and feedback of first-line people is most valuable in maintaining relevance and effectiveness.

Respect for the role of first-line people is demonstrated by providing not just the specification, *but also the purpose* for each task that they are required to perform (a combination of information that is rarely given in maintenance or asset management plans today).

The *purpose statement* (for a task or barrier) should identify what threat or failure mechanism is being addressed, and why. This concise statement (so often overlooked) is a valuable ingredient in the *design* to harness individual "mindfulness" which is the raw material for the collective workplace anticipation that contributes to *resilient* asset performance.

Design for practicality and effectiveness is part of the "M" in Asset Performance Management.

7 HIGH RELIABILITY ORGANISATION

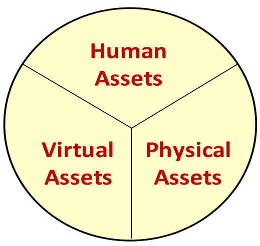
High Reliability Organisation (HRO) is a term used to describe organisations that are able to avoid losses most of the time, despite operating in environments where there is a high potential for error and losses. **When unexpected events do happen, HRO's are resilient in containing losses and recovering from the event**.

The concept of HRO's originated from 1980's research at Berkeley campus of University of California which focussed on the US Federal Aviation Authority air-traffic control system, the western USA Pacific Gas and Electricity electrical system (including the Diablo Canyon Nuclear Power Plant) and the peacetime flight operations of two US Navy Aircraft Carriers.[11] HRO's have evolved to manage circumstances with very high consequence of failure, and because the predominant theme is governance of safety (or duty of care), the principles can be applied to any organisation and any industry.

In parallel to HRO evolution during the latter 20th century, the Japanese revolutionized manufacturing industries by applying the interconnected set of disciplines that became known as "Lean Manufacturing". The Japanese brought superior asset performance and resilience to manufacturing processes through explicitly designed business processes that sought active accountability from all levels of the organisation. Lean Manufacturing not only eliminates wasted effort and resource, but also fosters a keen awareness in the workforce of "normal versus abnormal" at the places where value is created. This latter factor is positively reinforced by formal means of leadership presence in the workplace.

For many years, Japanese Lean Manufacturing baffled western industrialists because its principles were not transmitted through textbooks, but rather through the tacit experiences of the workers and the apparently invisible relationships with their leaders, underscored by an arcane way of thinking.

> *In this author's view, there is great resonance between the designed experience of Lean Manufacturing, and the characteristics exhibited by High Reliability Organisations. One sees that Lean Manufacturing approaches complex asset systems from the "east", and that HROs approach complex systems from the "west".*



Within the context of asset resilience, both the Lean Manufacturing and HRO approaches bring a profound emphasis to the **role of people** in achieving performance from asset systems. "Lean" has created new benchmarks in manufacturing, and its techniques have been copied and adapted to numerous other industries. HRO, however, is lesser known

[11] Weick, C & Sutcliffe, K *"Managing the Unexpected – Assuring High Performance in an Age of Uncertainty"* John Wiley & Sons, 2001

but gaining increasing attention due to the massive scale of man-made catastrophes, such as Piper Alpha (oil platform fire), Bhopal (toxic gas leak), Deepwater Horizon (oil spill), and Fukushima (nuclear contamination).

7.1 Mindful Organisational Culture

At the heart of both HRO and Lean Manufacturing is the notion (in HRO's terminology) called "mindfulness", which implies bringing one's entire attention to the present moment. HRO and Lean both *design* organisational cultures that create, and nurture mindfulness at individual, workgroup, and corporate levels. Weick and Sutcliffe[12] refer to this as creating a mindful infrastructure, and comment that "...individuals will be mindful only if there is mindfulness at an organisational level".

Why is mindfulness important in asset operations ?

- Firstly, mindfulness is a major ingredient in the anticipation of risk, the elimination of potential hazards and failures, and the proactive resolution of all manner of anomalies leading to loss, waste, and potential catastrophe.
- Secondly, loss due to deficient asset performance is a real-time phenomenon, and awareness of losses "in the present moment" captures opportunities that would otherwise never be realized. (Automation will cater for machinery and systems control, but humans are still operationally accountable for strategic direction and decision making on a continuous basis).
- Thirdly, given appropriate reason or encouragement, human beings have remarkable capacity to deal with complexity. This capacity can be easily "switched off" if the organisational attitude is not "collectively mindful".

7.2 Confronting Complexity

The scale of 21st century industry has introduced unprecedented complexity both within and surrounding large asset-intensive facilities. This complexity is described technically[13] by the notion of "variety" or variation across dimensions of the business such as requirements, demand, capability, effort, and subjectivity (or perceptions). Add to this the variety within the facilities themselves, such as physical environment, physical condition, wear and tear, software

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[12] Weick, C & Sutcliffe, K *"Managing the Unexpected – Assuring High Performance in an Age of Uncertainty"* John Wiley & Sons, 2001
[13] Ng, Irene et al, "*Complex Engineering Service Systems*" Springer, 2011

proliferation, and personnel skills. The idea of "controlling" complexity can become overwhelming.

A practical approach is suggested by Ashby's Law of Requisite Variety[14], which says that any effective control system must have equal or more than the number of variables in the system to be controlled. In other words, the asset system needs enough variety designed into it to effectively absorb the variety in the environment.

There are two design approaches for control in the presence of variety:

- Reduce variety by standardizing inputs and controlling the environment as much as possible (the classical quality, and lean manufacturing approach), and
- Design the system to be capable of absorbing more variety.

In the world of industrial assets, the first approach has been exhaustively optimized by the quality paradigm, and the practical techniques within Lean Manufacturing. The second approach is also implicit and tactile within Lean Manufacturing, but is also becoming explicit in the literature about High Reliability Organisations. In both Lean and HRO, the nurturing of individual and corporate mindfulness is central to resilient operations.

> *A very simple example of absorbing variety is where a well-organised receptionist might pacify a potential complainant with a smile and an attentive manner (controlling the situation).*
>
> *A powerful operational example is where an alert operator senses an abnormality in the noise produced by complex machinery, and calls upon engineering analysis.*
>
> *A technical example is where a tradesman working on one machine notices an oil leak on an adjacent machine, and fixes the leak whilst he is there.*

The second and third examples demonstrate human initiative focusing on proactive *Loss Prevention*. **These resilient outcomes** are much more likely to occur when the surrounding organisation is systematically mindful. This is an issue of *organisational design:* to build the capability of local problem solving (or, absorbing variety at a micro level, with leadership support on hand to absorb any excess variety).

In today's large and complex industrial facilities, the importance of a well-informed, alert and proactively-engaged workforce is critical to absorbing the variety that constantly challenges the productivity, and the very existence of those facilities.

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[14] William Ross Ashby, the neuroscientist who first formulated the Law of Requisite Variety http://en.wikipedia.org/wiki/William_Ross_Ashby

7.3 Framework for Organisational Improvement

Independent global research and experience in organisational safety,[15] and in reliability of large and complex assets[16] illustrate striking similarities of organisational culture, where outcomes improve as an organisation progresses through ascending levels of cultural maturity (or domains of behaviour).

These domains of behaviour are stable and self-reinforcing, in the sense that formal and informal business processes (or "the way we do things around here") conspire to form resistance to change.

This research shows that the cultural domain in which an organisation operates influences safety outcomes and asset performance. In particular the more mindful and proactively-engaged the workforce, the better is the organisation's reliability, safety, and asset performance, as illustrated in Figure 15 below.

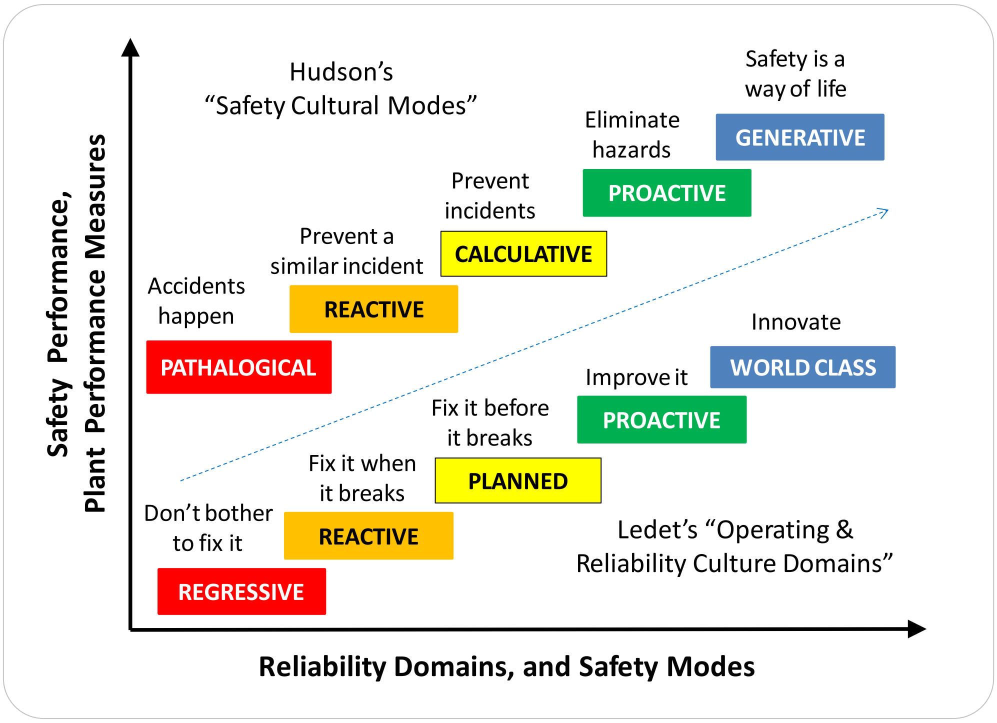

Figure 15 Domains of Behaviour for Reliability and Safety

Indeed, readers should not be surprised to find that High Reliability Organisations, and those successfully practicing Lean Manufacturing fall into the *Proactive* and *Generative/World Class* categories in the research studies.

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[15] Hudson, P. "Safety Culture – the Long, Hard and Winding Road", National Conference on Occupational Safety Management Systems, University of Western Sydney, 2000.

[16] Ledet, W. "Making the Move Toward a Learning Organization – a Classic Journey of Change", Ledet Enterprises Inc., 2002.

7.3.1 Practical Experience

To use a sporting metaphor, HROs and Lean practitioners are the *Olympic athletes* of the industrial world. The reality is, however, that most organisations are more like casual athletes than Olympians. Enterprises may be characterised entirely by one domain of behaviour, or more likely, have a mix of domain behaviours manifest in individual departments, or distinct business units.

Progression towards superior performance is an organisational "design and construction" effort. A favourable vision of the next domain must first be projected into the mindset of the existing workforce, so that the possibility of transition becomes credible and worthwhile[17].

> *An example of deliberate and sustained organisational change leading to superior business results is provided by Telstra's innovative relationship with a specialized asset management service provider*[18]. *This partnership produced an 80% improvement in network reliability, reductions of 40% in cost per amp, operating and maintenance cost reductions of 50%, with direct cost savings exceeding $200 million (2009 pricing).*
>
> *This superior resilience across the entire national network of telecommunications assets was achieved over a ten-year journey, by deliberately moving the service delivery organisation from a reactive culture in 2000 through the planned domain, and into the proactive domain by 2010. This case study is described in Figure 16 below.*[19]

It is important to note that the tactical objectives, measures and actions will be different for progression within and between each behavioural domain – there is no "one strategy fits all" for change on this scale. Design principles, however, are very pertinent and practical in the overall long-range strategy in moving from one domain to the next.

Design principles pertinent to this case study were, in part, inspired by the pioneering work of Mihay Csikzentmihalyi[20]. In the context of managing the performance of asset systems, these principles may be interpreted as follows:

- Objectives will be clear and understood by all levels of people within the organisation. Clarity of purpose is evident such that each individual may self-organize to align his or her efforts with the organisation's goals.

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[17] Ledet, W. "Making the Move Toward a Learning Organization – a Classic Journey of Change", Ledet Enterprises Inc., 2002.

[18] Cooper, B., Gordon, I., Bradford, A. *"Innovation and Improvement for Telstra's Energy and Cooling Systems: A Ten-Year Case Study"* INTELEC Conference, Orlando FL, June 2010.

[19] Ibid.

[20] Csikzentmihalyi, M *"Good Business – Leadership, Flow and the Making of Meaning"* Penguin Books 2004.

- The performance standards challenging the organisation (as determined by its leadership), will slightly lead the competencies currently exercised – thus stimulating growth and learning, rather than setting unrealistic expectations.
- People are equipped and enabled to achieve their objectives.
- People at all levels will receive rapid feedback of their performance, extending to real-time feedback at first-line functions.
- Variations to standard conditions and/or expected performance will be obvious and visual as soon as they occur – so that minimal disruption to "planned" or standard work occurs.
- Mastery of value-adding competencies will be encouraged, whilst non-standard work and informal practices discouraged.
- Knowledge Management systems capture important information and ensure that it is available to the people who need it.

Additionally, support systems get the right information & material to the right person at the right time. This factor is of grave importance where hazards to people and threats to the community at large are present.

	REGRESSIVE	REACTIVE	CALCULATIVE	PROACTIVE	GENERATIVE
Behaviour	Decaying. Issues and assets are being abandoned.	Overtime heroes. Waiting for something to happen and responding.	Planning. Preparing in advance to avoid chaos and surprises.	Searching out causes of failure (defects) and removing them before deterioration sets in.	Chronic anxiety regarding failures. Looking internally and externally seeking new opportunities and value.
Organisation & People	Organisation is driven by fear.	Success through heroic effort. Little coordination across functions and areas.	Groups working in coordinated & integrated way. Ongoing training & people development.	Clear performance measures and targets. People held accountable for performance.	Mindful and well-led people working is self-assured way. Effective work across internal and external boundaries.
Focus	Dispersed.	Problem of the day. Budget.	Avoid failures. Plant availability. Cost.	Value uptime & reliability. Competitive advantage.	Organization performance. Business growth.
Activities	Whatever feels right.	Determined by situation. Responding to crises. Fire-fighting.	Plan. Schedule. Coordinate.	Eliminate defects. Improve precision. Redesign.	Alignment of vision across business. Units integrating (logistics, marketing, operations).
Processes & Practices	Little documented procedures/ planning. "Who cares?" Mindset	Some procedures, some used, some not. Little or no planning "Just do it" mindset.	Documented standard operating procedures (SOP's). Planning done, compliance with the plan assumed.	SOP's well defined & used. Problems eliminated. Planning & compliance mature & reliable.	Ongoing SOP development and improvement embedded in "the way we work"
Application Software tools and platforms	Some spreadsheets.	Basic accounting. Many spreadsheets. Skunk-works databases.	Enterprise Resource Planning (ERP). Computer Maintenance Management system (CMMS).	ERP, CMMS. Asset Performance Management System (APM).	ERP, CMMS, and APM truly integrated with each other and with other systems.

Figure 16 Characteristics of Reliability Behavioural Domains

8 KNOWLEDGE MANAGEMENT TECHNOLOGY

Advances in Knowledge Management Technologies (KMT) have brought powerful supporting features for implementing Asset Performance Management (APM), and for the nurturing of High Reliability Organisations (HRO).

Traditionally, the operation of large and complex facilities relied upon the competence of technical specialists to manage corporate knowledge. Detailed information was stored in "stove-pipe" databases that retained organisational power and inhibited information transmission between departments, and between major asset transitions (such as between design, construction, and operation).

In recent years, the explosive growth of information technology has led to two profound shifts that have radically changed the way organisations are managed[21]. "Firstly, global knowledge can now be accessed instantaneously by anyone from anywhere... Secondly, production work can be automated and therefore operated from anywhere, meaning that geographically based hierarchies have become superfluous and are disappearing fast... New ways of knowledge production, access, distribution, and ownership are emerging..." opening up the organisational possibilities for "natural social networks (communities of interest), and centres of excellence to inform work practices" and sustain corporate knowledge. Global experience of working within the Covid-19 pandemic has accelerated this trend.

Theoretically, it is now possible to get the right information to the right person at the right time, to do the right thing in any scenario that can be imagined. The emergence of the **Digital Transformation of Industry** as a vendor-encouraged strategy to upgrade KMT certainly has this potential.

However, the challenge remains: ***what is the right thing to do,*** and how to create a defendable strategy for sustaining industrial performance in the presence of unprecedented complexity and compounding risks ?

Digital Transformation (including "data science" and "digital twins") undoubtably improves the management of facilities at a tactical level, and greatly enhances the ongoing task of synchronising the information between the three aspects (physical, virtual, and human assets), However Digital Transformation still needs to be framed within context of competent risk management, sound operational experience, and a legally-defendable strategic approach.

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[21] Malherbe, G. & Stanway, G., *"The Thin Operating Platform Model – a discussion paper"* Virtual Consulting International, www.govci.com

8.1 Asset Management Software

An administration layer of Knowledge Management Technology (KMT) is now available to manage the three asset dimensions (physical, virtual, and human). This KMT has emerged from four distinct types of applications software briefly described below:

- **Enterprise Resource Planning (ERP)** - managing the totality of an enterprise's value stream and cash flow. ERP's have modules covering the functions of asset registration, maintenance, stores (spare parts), and procurement. ERP's are strong in managing the transactional aspect of physical assets for cost accounting purposes.

- **Enterprise Asset Management (EAM)** – specialising in the administration of activities and physical status of assets, including work planning, resource administration, cost accounting, asset status and relationships including spare parts, and geospatial configurations. Most contemporary EAM systems evolved from the family of software known as CMMS (computerized maintenance management systems).

- **Product Lifecycle Management (PLM)** – managing the cradle-to-grave configuration of complex assets in all their versions such as an evolving fleet of aircraft, and tracking each aircraft's configuration through its life.

- **Asset Performance Management (APM)** – the most recent family to emerge – designed to create reliability & integrity strategies for operational scenarios, and to analyse the condition and performance of operational assets against the expectations of those strategies. APM software aims to connect the technologies of inspection, instrumentation, and control systems with transactional history (ERP and EAM) to analyse and assess the effectiveness of reliability and integrity strategies.

These large-scale databases contain immensely valuable corporate knowledge. They are all implicit attempts to apply Ashby's Law of Requisite Variety[22]. It is also clear that on this scale, the older paradigm of technical specialists coordinating knowledge (using personal productivity tools such as spreadsheets) presents a significant risk to the safe operation of large facilities, due to information corruption, dispersion, and/or loss.

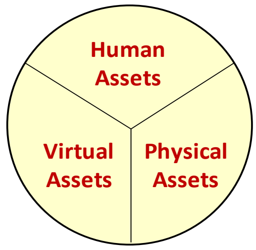
Whilst there are no clear boundaries between the four families above, there are many overlapping areas of functionality. Their respective themes continue to weave, merge, and separate again, as software tools evolve under the banner of **Digital Transformation**. This cloud-based technology embraces a vision of the Industrial Internet of Things (IIoT), and the emerging disciplines using "big data", "data science", and "digital twins".

[22] "any effective control system must have equal or more than the number of variables in the system to be controlled.

8.2 Putting Software into Perspective

Very large-scale software systems have evolved to assist humans to manage the complexities of operating today's industrial facilities. Indeed, the software and associated infrastructure have emerged as critical assets in their own right.

The knowledge-containing element (the "virtual" assets) now mirrors the detail and complexity of the physical assets, as its senior purpose is to form the bridge of understanding between the physical assets and the human assets, enabling people to interpret, decide, act, and review their interactions with the physical world.



However, managing the sheer volume of detail that is embedded and perpetuated in these software systems is a formidable and resource-intensive task. All manner of automation and smart algorithms are programmed to interact with the complexity of the real world, and to maintain resilience at a tactical level (close to where activities occur) - from automated process control to pre-programmed transactions for goods and services. Indeed, it is at this tactical level that the software conglomerate may seem to assume a life of its own.

But how is this burgeoning conglomeration of software governed ? Specifically:

- how are owners assured that their physical assets are safely performing their intended functions, and are not exposing owners to catastrophic risks ?
- How can software be *strategically positioned* to bring confidence that the risks associated with large and complex facilities are controlled ?

The answer lies in first establishing the really important information about asset condition and performance, from the ocean of detail that is currently digitally available. Then, adding corporate knowledge and technical value, so that the resulting actionable knowledge is "front-of–mind" in the operational organisation.

Technology is now capable of supporting this endeavour, which is a powerful enabler for the "High Reliability Organisation", and a crucial weapon in *Loss Prevention*.

8.2.1 The Really Important Asset Information

Simply stated, the really important information about industrial assets is the knowledge of what can cause catastrophic losses to the business. These catastrophic losses may arise from singular events, or chronic latent conditions. They may be caused by physical mechanisms, or by procedural failure, corruption of information, fraud, or lack of security.

Considering the integrity of physical assets within a facility, the critical pieces of information that need to be identified and regularly tracked are:

- How does the equipment and/or procedure fail (what is the mechanism of failure) ?
- How can onset or deterioration be detected, and how often must that mechanism be monitored ?
- How can the mechanism of failure be prevented, or delayed ?
- If the mechanism does occur, how can the effect of failure be reduced or mitigated ?

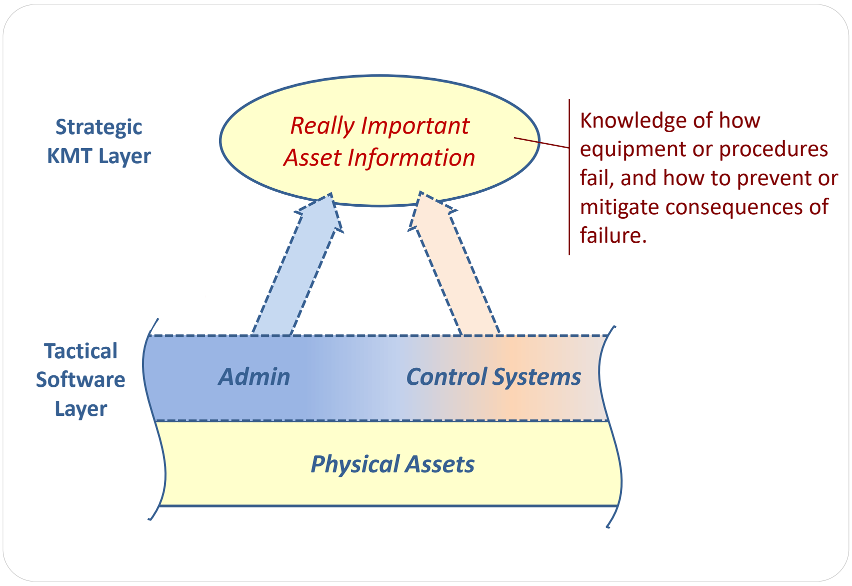


Figure 17 Important Asset Information

This is a risk assessment or emergency planning exercise when considering a single item of equipment. However, at the scale of large, complex, and interrelated facilities, sophisticated KMT is needed to aggregate and prioritize risks across the enterprise, thereby matching the real-world variety in condition and time. The "**Strategic KMT Layer**" in Figure 17 is required to flag conditions of potential failure (such as deterioration), and to retain the ever-evolving corporate knowledge that should hold answers to the questions above.

8.2.2 The Important Actions

The next powerful use of the Strategic KMT Layer is to provide the concise intelligence to enable people to plan for appropriate actions, especially **conveying the purpose for the actions required** (the threat, the mechanism of failure, and the potential consequence).

Then, the crucial information to be delivered to the Admin Layer (for detailed planning by operations staff) is "**what to do, when, where and why**" (either to prevent failure, or to recover from the event). These are the *Loss Prevention* strategies mobilised across the enterprise.

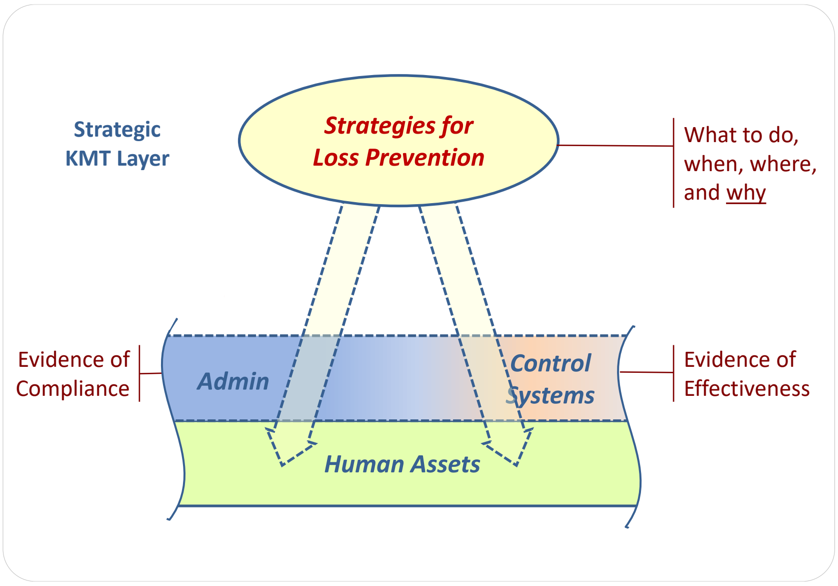


Figure 18 Strategic Actions for Loss Prevention

A simple example of *Loss Prevention* is illustrated in the table below. It is included here to emphasise that at this level, the strategy is deliberately not detailed. Rather, it is designed to create stakeholder agreement, to give direction to the wider organisation, and to be delegated to others for detailed planning and action (i.e. the "how").

Loss Prevention Example – to avoid injury or lost travel time by motor vehicle				
Consequence	**Failure**	**Due to**	**Mitigation**	**Action plan**
Crash	Tyre	Wear	Monitor condition	Observe tyre wear indicator
		Puncture	None (accept failure)	Carry spare part
	Driver	Loss of control	Safety standards	Regulate design standards
Immobilisation	Engine	Poor lubrication	Periodic service	Replace oil
	Electrics	No ignition	Insurance	Phone Auto Club

In the context of a sophisticated regulatory environment, with continuously changing business conditions and objectives, it is important that the loss prevention strategies are not only being done, but also being seen to be done. Accordingly, the strategic KMT layer should also accumulate the following important verifications:

- Evidence of compliance (that the organisation is doing what it plans to do), and
- Evidence of effectiveness (that the plan is indeed effective in *proactively* controlling losses).

9 GOVERNANCE FRAMEWORK

Considering owners' societal obligations in the context of a catastrophe, the law adopts the view of legal causation, which is *necessarily hindsight-based*. That is, our community's sense of justice requires that blame must be assigned.

It is the owners' duty of care to take every reasonable precaution to prevent failure and/or harm. How is governance applied to ensure this duty of care ? And where is the evidence of this governance ?

In order to *demonstrate* governance, the following evidence must be in place:

- Evidence - that a strong and defendable PLAN is in place (the plan has integrity).
- Evidence - that the organisation is complying with the PLAN.
- Evidence - that the PLAN is effective.

  A strong and defendable PLAN will have the following features:

  - The PLAN is based on good science, and accurate information.
  - The PLAN is prepared by competent people.
  - The PLAN is relevant to current operational conditions.
  - The PLAN is approved by an accountable person.
  - The PLAN is consistently applied.
  - The PLAN is regularly reviewed, assessed, and amended as necessary.

The table below provides an example of the types of evidence that should be collected, to demonstrate ongoing governance in asset-intensive enterprises:

The PLAN:	**The "Asset Portfolio" (at Enterprise Level)**
1. Integrity	○ Do I have a *valid (strong & defendable)* Plan ? ○ Have my assets been subjected to a *valid* Criticality Assessment ? ○ Are all *High-Consequence-of-Failure* assets covered by *valid* Risk Assessments (RCM, HAZOP, etc) ? ○ Are all *High-Consequence-of-Failure* assets covered by *valid* Preventive Maintenance and Mitigation plans ?
2. Compliance	○ Are we doing what we promised to do ? ○ Are our resources working on the right things (firstly, covering our risks) ? ○ Is the plan being refreshed with new information ? ○ Are generation losses being recorded (daily) against my assets ?
3. Effectiveness	○ Are asset-related safety incidents increasing or decreasing ? ○ Are asset-related losses stable, improving, or deteriorating (considering both frequency and magnitude) ? ○ Is the productivity of assets stable, improving, or deteriorating ? ○ Can production performance be correlated with the asset register, and asset history ? ○ What is the cost of maintenance (in various scenarios) over the next X years ? Can I smooth the cash-flow ? ○ How do I judge the effectiveness of new capital installations ? ○ Is the current maintenance regime cost effective ?

Figure 19 High-level Governance Questions

It is to these questions (and more), that the *Loss Prevention Imperative* is formulated and applied - through APM strategies aggregated in a strategic KMT layer, and mobilized in a workforce attuned to the principles exhibited by High Reliability Organisations.

Clarity of Purpose within the Plan

The value of having an engaged and committed workforce is an invaluable deterrent to the myriad variations and complexities that arise daily in the industrial workplace. Indeed, the ability of a workforce to deal with variation may be described as "resilient".

The critical role of "meaning" cannot be underestimated – sometimes the most brilliant strategies *will fail* because the underlying meaning has not been accepted by those that must execute the intent.

So, "clarity of purpose" means the disciplined and precise expression of corporate intent, which is *meticulously* conveyed to all workgroups within the enterprise - *with content and language specific to their roles*. In this regard, "form" is as valuable as function, in that visibility of purpose is enhanced and readily understood by those who execute.

A structure for "clarity-of-purpose" may be demonstrated by a consistent application of definitions of Objectives and Strategies, from executive level to the front-line operational levels of expression within an enterprise. Examples of practical definitions are:

Objective	A desired end-result or condition, or the desired future state of an object or situation. *(Expressed as a Noun-verb-object sentence in the present tense).* *Eg: "The Company earns community respect and support"*
Measure	An indicator that gauges progress towards accomplishment of an Objective. A measure is a quantifiable aspect of the Objective**.** *Eg. Number of community complaints*
Target	An expectation – an achievable point on the scale of the measure. Every Objective should have at least one quantifiable measure with a corresponding credible target.
Strategy	The intended approach for accomplishing an Objective. *(Expressed as a Verb-object statement).* *Eg: "Conduct quarterly community meetings and solicit feedback"*

Governance and alignment of activity is achieved by ensuring that the higher-level objectives have supporting objectives that aim to satisfy the strategies promulgated at the parent level. When committed to plain language, such a hierarchy presents a thoughtful expression of leadership, which is invaluable for gaining the proactive participation of front-line personnel.

10 CONCLUSION

This paper is confined to the industrial asset systems manifest in large and complex facilities and portfolios of facilities. It is proposed that a comprehensive approach called the ***"Loss Prevention Imperative"*** delivers both risk reduction, and superior asset performance - by the diminution of chronic historical losses, and by reducing the likelihood of catastrophic events.

The *Loss Prevention Imperative* combines the resilient virtues of a "High Reliability Organisation" (HRO) with the incisive technical discipline of "Asset Performance Management" (APM), and is mobilized within an enterprise-scale strategic layer of Knowledge Management Technology (KMT).

An essential enabler is that currently available KMT be configured with appropriate strategies for loss prevention and governance, so that:

- The most important information flows to the right people at the right time,
- scenarios of genuine high risk can be addressed with greater diligence and confidence, and
- asset productivity can be improved without significant capital injection.

This approach is a practical and defendable application of due diligence in managing industrial facilities - an approach where superior practices may be extended confidently across multiple regulatory jurisdictions.

The strategy is carefully designed *Industrial Resilience*.

The outcome is more robust and effective *Loss Prevention.*

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