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A Holistic Power Systems Asset Engineering and Decision Management Framework for Railway Asset Managers

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Abstract

Defining, designing and implementing an asset management system capable of effectively managing assets throughout their life in terms of engineering, financial, digital and stakeholder needs is challenging. Furthermore, governance frameworks of the past have traditionally resulted in 'silo' type asset interventions without considering the total sustainability of system outcomes. In this paper the writers set out a governance framework definition suitable for managing the complex adaptive needs of engineering, financial, digital and stakeholder requirements. In addition, it will set out the components of a framework that can manage complex assemblage of assets by using bottom up aggregation of 'asset realities' and the 'business' or outcomes needs based on stakeholder, socio-economic, technical and or business strategy requirements.

Introduction

A exhibits positive and continuous results across power systems companies [1]. Previously research and cademia and industry have struggled to find a comprehensive, consistent and applied asset management framework that approaches to managing electrical power systems have resulted in 'silo' like contributions and lack in overall system governance; economic viability [2] or ability to find causes to issues, for example related to infrastructure faults [3]. Moreover, examples spanning many years have demonstrated the difficulties in providing long term, consistent and measurable asset management decisions [4,5]. In the past Asset Management in a power system engineering context has largely been 'maintenance' focused and has often resulted in singular topics of asset management being advanced. In this paper the writers will outline a holistic and adaptive asset engineering and decision management framework that enables companies to consider the structure, documents, inputs and governance required to effectively balance the holistic requirements of building, managing, operating and selecting end of life decisions regarding power systems assets.

Asset Management System Framework

The writers make use of novel approaches in hypothesised frameworks. The Asset Management system framework utilises a top down and bottom up approach to create a consistent, assured and well documented suite of best practices across the whole life of the assets. This will be expanded in greater detailed throughout the sections of this paper (Figure 1).

Thinking of physical, financial, digital & stakeholder

This system framework combines business and engineering requirements to provide better visibility of the various asset strategies and plans. It also provides the basis by which the company can continuously trace actions, assumptions and criteria by which to measure the decision effectiveness. It does so by combining bottom up asset engineering strategy definition in the Asset Class Strategy (ACS's) whilst helping engineering teams to consider the system of assets and outcomes required of the business to remain viable. Whilst ensuring sustainability in terms of financial and business-related needs. Taking this approach means that strategic and financial policy makers will more equipped to consider the 'reality of the assets' when determining short term asset intervention requirements whilst considerate of financial planning; This enables a maturity based approach to asset decision making across all areas of the system. Framework as it is applied in the real-world setting – bridging financial, digital and physical planning cycles. This becomes increasingly needed as various incentives and financial packages are offered to develop infrastructure solutions. Of which need to be engineeringly sound, reliable, maintainable, flexible and economically sustainable [2]. This paper sets out the system criteria and overall definitions required to achieve a holistic approach to asset management decision making, it will also provide a structure that enables technical, financial and strategic decisions to be made with greater detail. Aggregating asset needs through a critical 'line of sight' to ensure business, engineering and financial outcomes are documented and appraised in varying time constraints. Lastly the paper will conclude with benefits, improvements, constraints and limitations of the system framework (Figure 2).

Business objectives

The asset management system framework must consolidate the business needs, requirements and objections over a defined period. Often in regulated industries this is the Strategic Business Plan or documents as part of a regulatory review cycle. It is also important to consult with stakeholder groups when defining the objectives in order to create the most effective asset strategies. Intern the business should consult with stakeholders on the weighting by which it should consider the objectives importance. It is also recommended that where possible the Business Objectives are long term and stretch several entire budget periods where possible. For example, a lifecycle cost approach to inform multidecade business and asset needs.

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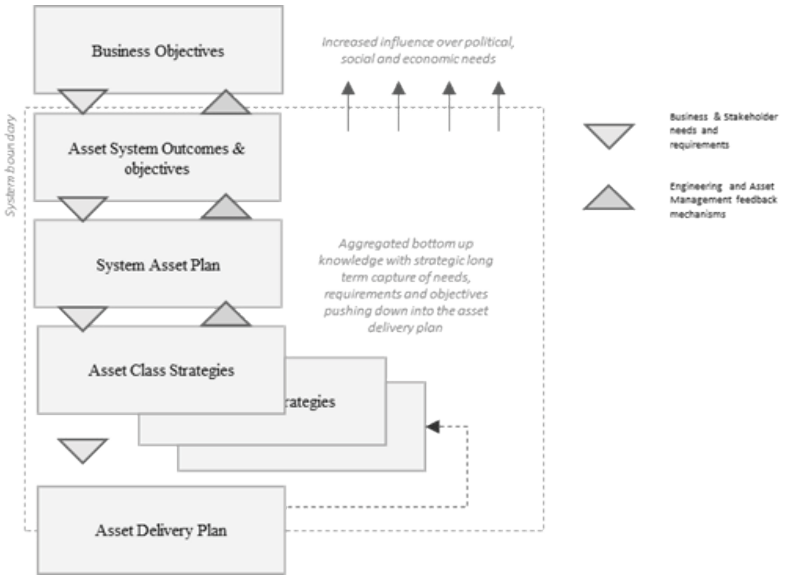


Figure 1: Asset Management Framework.

Figure 2: Alignment to business planning cycles and objectives.

Asset system outcomes aligned to business objectives

The company should define key principles with measurable performance (cost, risk or asset performance) that will enable it to manage its assets in accordance with the strategic business plan and objectives set out above. This could be a document or a KPI measure implemented against the business objectives. It is important to note that the Asset Objectives must be derived from business objectives and should be weighted in terms of their importance. Thus, creating a consistent method of evaluation and more importantly allow for varying levels of the business to act with independent 'time' needs. It is also important at this point that all the assets in ownership or legal jurisdiction of the company are defined (Figure 3).

Overarching system asset management plan (SAMP)

The overarching system asset management plan or referred to by some as strategic asset management will define the total assets in the portfolio at a high level but will also provide the long term consolidated view of the aggregated bottom up asset class strategies. This document will be used to consult with the strategic business plan on an ongoing basis and provide the translation between business and system needs. It will also set out the organisational plan to help support the asset management system through organisational, financial, people or otherwise.

Asset class strategies (ACS)

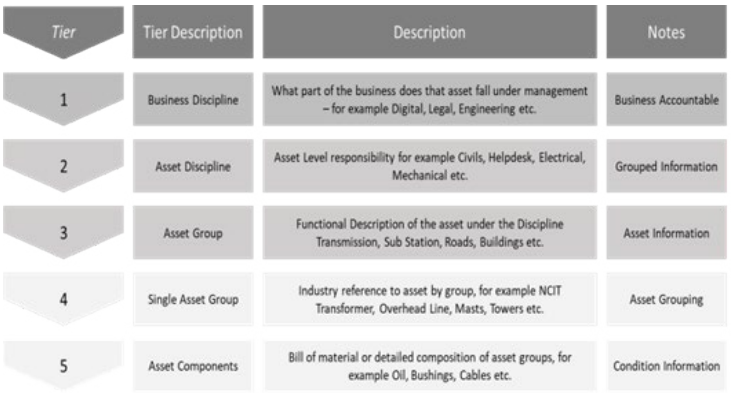
Asset Class Strategies are grouped by relevant engineering function or by ownership. For example, Civil, Electrical, Operational Buildings, Operations. Note: this framework does not limit to the number of asset class strategies. In this manner the framework can adapt to changing needs of the business. It is important to note the Asset Class Strategies will include the full assets within that class grouping at an aggregated bottom up level.

Asset delivery plan (ADP)

This is the schedule of work and the resources to conduct the work in accordance with the strategies' set out in the asset class strategy. Whilst many companies may have different systems for organising projects, people and teams the need to identify which activity is associated to the asset class strategy is key to ensuring traceability between the 'bottom up' actual work compared with the reasons for doing the work as outlined in more detail in this section.

Systems Asset Management (SAMP)

The purpose of the System Asset Management Plan (SAMP) is to provide documented decision-making context, support, guidance and



Tier	Tier Description	Description	Notes
1	Business Discipline	What part of the business does that asset fall under management – for example Digital, Legal, Engineering etc.	Business Accountable
2	Asset Discipline	Asset Level responsibility for example Civils, Helpdesk, Electrical, Mechanical etc.	Grouped Information
3	Asset Group	Functional Description of the asset under the Discipline Transmission, Sub Station, Roads, Buildings etc.	Asset Information
4	Single Asset Group	Industry reference to asset by group, for example NCIT Transformer, Overhead Line, Masts, Towers etc.	Asset Grouping
5	Asset Components	Bill of material or detailed composition of asset groups, for example Oil, Bushings, Cables etc.	Condition Information

Figure 3: Example Asset Hierarchy.

tools related to the capital build, maintenance, renewal and operation of the company and its assets. This section will outline the criteria required.

Safety & compliance

In this section of the document the company must outline its safety programmes and offer guidance on relevant standards and procedures. This will create consistency across each of the ACS documents. Topics should include at a minimum:

- Safety Campagins
- Safety Targets and Measures
- Safety Analysis
- Including high level safety analysis
- The company should adopt best practice in ALARP [6] Safety Management

Business, organisational & stakeholder information

This section will outline the relevant business and organizational context of the company and highlight any commercial, technical or political points regarding contractual or stakeholder requirements that influence the asset management decision making processes. Topics should include:

- Contractural Requirements
- Sakeholder Interactions and plans
- Business Peformance Requirements
- Asset Capability Requirements
- What function, group or individuals are responsible for the asset management system framework maintenance

Asset composition and description

The overall assets across the company and the count of those assets at a grouped level. It will be the responsibility of the owner of the SAMP document to audit the assets defined in the ACS are in accordance with the total asset inventory. This section will also detail the digital replica or information requirements regarding the physical and financial assets in the scope of the business context. In this section the following should be covered:

Asset Information Definitions

- Asset Portfolio Scope, Boundaries & Interfaces
- Condition & Performance Overview
- Future Condition & Performance Trends
- Obsolescence Management needs based on ACS's
- How the business will assure the validation of the asset inventory and information set out in ACS's

Asset criticality using the asset system outcomes objectives

Asset criticality can be thought of in this context as the relative importance of an asset or system to the successful delivery of the organizational goals and objectives (including legal requirements). Understanding the criticality of assets enables improved decision making and management of risk. The company must assess on a regular basis the asset criticality. The company should weight and score the asset criticality using the appropriate industry relevant practices, one example is using a *5x5* or *10x10* [7] risk matrix approach. The Asset Criticality ranking will be used to help direct the approaches to capital, operations, maintenance, renewals and disposal etc. In this first instance the business responsible function of the SAMP should use the objectives as outlined above to determine the impact of asset performance changes (Cost, Risk, Performance & Safety).The responsible functions for the ACS's will consult and provide feedback to the SAMP responsible parties with the company to ensure that from an engineering integrity and risk mitigation that the criticality is as accurate and timely as possible. This must be updated in line with the Governance, Audit and Assurance regimes as outline in this framework.

Lifecycle management

Lifecycle management brings together the existing guidance, recommendations and targets outlined within the ACS's and the business strategic plans. This enables a common evidenced approach to ensure that the asset systems and the asset portfolio are managed holistically, whilst ensuring compliance with safety and assurance needs. For guidance it is recommended that the following should be considered as lifecycle management options and modelled for the lifecycle implications on the asset system objectives in conjunction with the ACS's. These are:

§ Do nothing – the effect of not maintain or renewing the assets in question

§ Managed decline – the effect of degrading an asset

§ Basic Maintenance – the minimal safe need

§ Current Maintenance – the difference between the minimal and current regime

§ Vary Refurbishment – the impact on the objectives in varying the refurbishment cycles of assets

§ Vary Replacement - the impact on the objectives in varying the replacement cycles of assets

§ Enhancement - the impact on the objectives in enhancing assets (such as condition monitoring)

§ Opportunities to re-use or reconfigure assets

It is important to note that these scenarios must be considered not in silo; for example, varying the replacement schedules based on remaining useful life will have an impact on maintenance needs. These models will need to consider the total cost of ownership of the assets in question when considering the options available to the business. It is furthermore important to consider the aggregated view of the ACS's on critical assets and those of highest safety requirement.

Continuous improvement

Feedback loops will be defined in the SAMP based on ACS's and timeliness of aggregate chances in condition, reliability, spares, safety etc. events from the ADP. This will mean that the responsible function for the SAMP must review and audit the ACS's in accordance with the audit review principles of the company and as defined in the SAMP and ACS's. It is important for the company to re-baseline at each review to determine trends, understand strategy appropriateness, risks and opportunities whilst consider with financing implications (Figure 4).

Audit & review

This section shall outline the audit and review needs – however it is recommended that the company utilises internal competent personnel and third-party auditors on a regular ongoing basis. Once ISO 55001 certification is achieved audit provisions can be established in line with the standard.

Asset Class Strategy (ASC)

The purpose of the Asset Class Strategy is to optimise asset lifetime performance through the adoption of a structured whole-life approach to capital, operations, maintenance, renewal, *disposal or changes* to asset configurations (such as in a reuse scenario). This section of the framework must outline which assets are in the scope of its control (for example Generation, Power Transmission, Distribution, etc.) including but not limited to:

- The types and volumes of assets in scope of this asset type in accordance with corporate liabilities and ownership;
- The status of these assets in terms of their current performance, historic performance and criticality;
- The lifecycle cost modelling and options considered for managing the assets and the impact each option would have on the current and future levels of service;
- The chosen approach to managing the assets, including considering the planning of work volumes to deliver the business objectives and levels of service for the lowest lifecycle cost or weighted affordability for service outcomes;
- The information requirements and development plans to support current and future decision making; and
- A summary of the defined strategy for each asset type, its justification and plans for future development.

Related documents & context

Reference key documents and where this document sits in the asset class framework as in line with the Asset Management system Framework and where documents may relate to stakeholders outside the scope of the company's asset or business boundaries. It is important to note the review dates of industry changes to interface documents outside of the organisation.

Stakeholders (internal & external)

List of define each of the stakeholders in connection with the asset class strategy. Including where asset class may interface with other asset classes.

Objectives & Levels of Service

Objectives can include safety, reliability, maintainability or availability targets of each of the asset class. These objectives must reflect the Business Objectives and clearly demonstrate a link between the asset class objectives and levels of service and how this supports the overall business objectives as defined in the asset management system framework, Business Objectives.

Asset Composition & Description

Definitions

Asset Class Strategy must list all Asset Definitions with clear description and preferably images of which physical assets the definition is referring to.

Hierarchy

The Asset Hierarchies will use the definitions above and set out in a structure manner the level of which asset shall be categorised. For example, Asset Class Strategy Air-Insulated Substation, of with asset definition of transformer, and at the lowest level of inventory captured by the organisation bushings etc. Note: it is possible to utilise existing parent, child relationships and structured asset definitions based on other standards, for example as BIM.

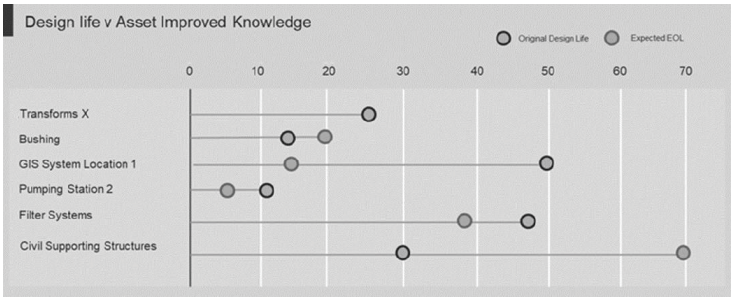


Figure 4: Example Expected End of life vs Previous Baseline.

Assumptions

The document should contain a reference list of assumptions, including at a minimum the following:

- Reference to page number
- Reference to the asset in question (As defined in inventory bellow)
- Data of Assumption
- Data Source (Internal Staff, External Journal, RIDDOR Event etc.)
- Last reviewed
- Latest review to be conducted (i.e. next review)
- Is Critical (Safety, Performance, Risk or Cost)

Asset count & inventory

The inventory section must utilise the same definitions as above and give the following:

Reference to definition above

Locations summaries (single site, multiple locations, specific areas of interest, near wildlife/conservation areas etc.) – Please note that specific geo-coordinates for each asset will be logged in the asset maintenance system or register.

- Volumes such as number, length, weight etc. for each asset defined
- Volumes of spares including critical spare levels identified
- Any comments or noteworthy information about the inventory (such as sole supplier information, one off design, obsolete etc.)

RACI

This section should document the business areas of functions and if needed specific roles that hold responsibilities accountabilities, contributors (RACI) and informed partiers across each of the assets defined in this asset class strategy.

Therefore, the RACI [8] must provide clear accountability and responsibility of individuals against activity and task.

Roles and responsibilities are key to ensuring individuals are held to account in their role, the above table provides such clarity. The second benefit of the RACI chart is to identify those roles requiring consultation and wider informant of specific activities.

Competence management

This section should identify the necessary competences to fulfil activities identified with the document. It should also recognise the resources of the business when developing strategies to whole life cycle decision. For example, if there are not enough dissolved gas analysis personnel who are competent and capable of performing such testing then a strategy based on condition sampling of transformer oil would not be appropriate.

Asset capability

This section must outline what capability the assets defined with the asset class strategy must be able to undertake. For example, an enclosure of a Gas Insulated Sub Station will need to be capable of withstanding operating needs of the local environment etc.

Asset condition / reliability

The asset class strategy must set out the condition scoring metrics that are used across each asset definition and volume. Where possible it is recommended to consolidate condition scoring into a simple numeric representation of the asset across its lifecycle (in accordance with the definitions agreed in the SAMP for achieving business needs). The Asset Class Strategy must for each of the assets defined in the hierarchy and volumes give the condition and or reliability measures. Where possible and assets have been installed for some length of time it is recommend that the condition of time or deterioration is also demonstrated.Where possible empirical and statistical modelling should be used, where data quality is questionable or unattainable (for example historically) then qualitative engineering judgement can be made of the expected condition over a defined period, load, stress or utilisation. However, it is important to identify improvements, where possible to increase the information confidence by which these predictions are made.

Asset age profile & remaining useful life predictions

For each asset definition this section must capture a) the original design life, b) the forecast remaining useful life predictions over time and c) the current expected end of life. In addition, this section should cover the following:

- Asset Type (reference to inventory)
- Date Manufactured
- Date Installed
- Date Commissioned
- Dates of calibrations / certifications
- Original Design life
- Predicted end of life (over time)
- Current expected end of life
- Comments and explanations (including external papers, journals, articles, conferences etc.)

Key asset / operational issues

In this section for each asset defined in the asset class strategy a list of issues, lessons and operational challenges must be captured. If unknown or as a result of a new asset class, then a clear link to the asset risks / criticality must be documented.

Expenditure

In this section all the associated expenditure appropriated to the assets defined above shall be proportioned. Where possible using activity-based costing estimates.

Risk, Opportunity & Criticality

Approaches to risk management

Whilst common objectives scored in alignment with asset criticality will provide a risk-based approach by which to identify decisions it is understood that risk frameworks have developed at different levels in various applications. Whilst moving to a single definition of risk for the entire business will inevitably provide a clearer mechanism for communication risk it is important that a base level of alignment between the ACS exists, therefore this section should document the

overall asset and companywide approach to risk management. If risks systems are different to the asset categorisation in the ACS then this section must include a Accountants in Business Committee [9]. Reference lexicon between definitions, approaches and standards. Thus, ensuring traceability and alignment with risk management practices.

Governance and compliance

This section must outline what governance and compliance approach the company will be following. For example, three-line assurance techniques using self-assurance, manager and third-party expert assurance etc. It is recommended that the ACS and the ADP are randomly sampled for timeliness, quality of information, assumptions and engineering assurance purposes [10-13].

ACS audit regimes

How and when shall the ACS be audited and identify the necessary audit assessor roles both internally and externally. It is recommended to annually review the ACS until such time that audit regimes in line with the asset risk, performance or business needs can be established. It may be needed for more regular reviews if the strategies so deem appropriate.

Asset criticality definition

The ACS should utilise the SAMP Asset System Outcomes objectives to build a criticality matrix for each of its assets [14-16].

Asset criticality

This section should identify how the components of risk; Asset Criticality and Locational Criticality are used to drive inspection, maintenance regimes and intervention levels. Scores are as a result of an assessment against each of the Asset System Objectives

Obsolescence approach and management

This section should identify the key supply chains for each asset defined above. This section should include reference to remaining useful life predictions and easy of stock / procurement in the event of an Obsolescence risk be determined in the failure modes [17-19]. It is recommended that where possible the company incentives the suppliers to notify them about obsolete parts or systems where possible in advanced of budgeting cycles for the company (Figures 5 and 6).

Location criticality

This section should define any location specific risks or criticalities such as terrain, environmental threats, local populations etc.

Operational resilience

This section should identify any failure modes identified in the Asset Risks section with mitigation strategies for each. It is important to note that some assets of a lower criticality, with failure modes that could be highly unlikely and with a low impact on the objectives may require very little mitigation other than defined monitoring periods in accordance with safety regulations or best practice as an example.

Asset failure risks

For each asset defined, this section must reference detailed Failure

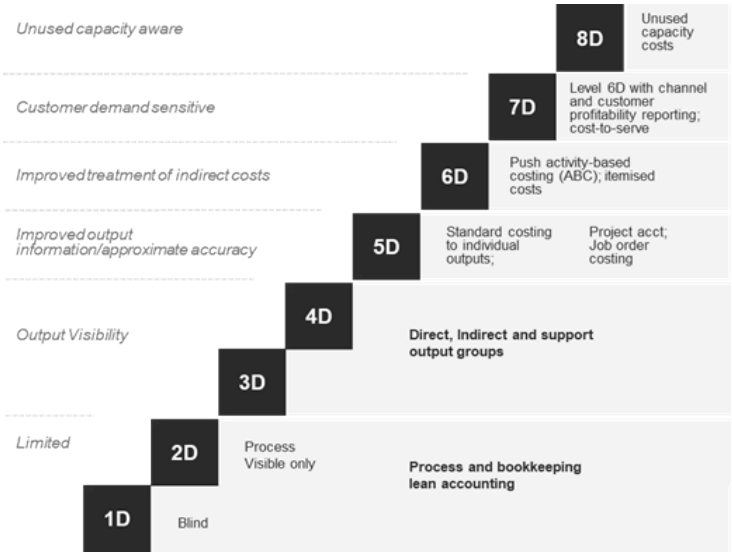


Figure 5: A costing levels continuum maturity model (Professional).

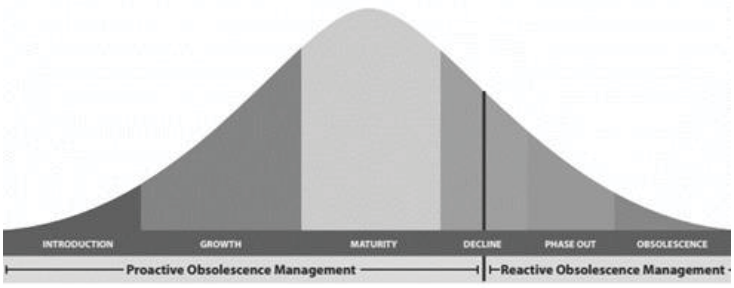


Figure 6: Obsolescence Management.

Modes and Effects Analysis (FMEA). For ease of use it is recommended that a summary table be included of the highest impact, most likely failure modes. And a summary of the failure mode analysis of the past. This becomes very useful in determining competence management of resources in the asset delivery plan [20-22].

Lifecycle Management Strategies

- For each asset defined above this section must include the following:
  - Asset Type (reference to inventory)
  - Asset Group (Parent Asset)
  - Asset Influences 'Risk, Cost, Performance, Safety'
  - Criticality
  - Inspection Approach & Reasons
  - Maintenance Approach & Reasons
  - Renewals Approach & Reasons
  - Commentary and explanation

Conclusions

The proposed framework would help infrastructure managers better identify the criteria by which to create a consistent and applied engineering framework to managing risks, costs and performance needs of electrical power system assets in a holistic view. In addition, the combining of business and asset objectives into a single criticality matrix as shown above would enable a single view of the asset needs and interventions to become visible and traceable. This would also enable a connection between the delivery plans and the strategy by which assets are managed over their life. This combination and synchronisation of the business needs as combined outcome would over time enable a maturing asset decision framework to better enable the power company meet changes needs. It would also over time remove the legacy 'silo', none connected intra-company requirements; aligning the entire physical, financial and digital needs to the business outcomes. It is also recognised that in a real-world application of the framework various interventions would be dependent on several hard and soft constraints. For example, in the context of a regulated industry with financial planning cycles of five years it is understood that the maturity of this framework will not realise full benefits from its initial implementation. However, case studies and its application will be used to demonstrate the frameworks increased transparency of complex adaptive contributions (Such as deterioration, condition, performance and financial risk). So that business plans and engineering knowledge combine with defined objectives, thus this system framework can evolve over time to better meet the system outcomes of assets that create a continuously updated and sustainable business of managing such asset classes.

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