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A Model-Based Systems Engineering approach to developing an Asset Management framework for rail organisations

Bradley Hocking
Shoal Engineering Pty Ltd
bradley.hocking@shoalgroup.com

Chris Sproston
Shoal Engineering Pty Ltd
chris.sproston@shoalgroup.com

ABSTRACT

Successful implementation of Asset Management (AM) principles is key to a rail organisation's ability to realise maximum value from its assets. The success of this implementation is based on the structure, maturity and useability of the organisation's Asset Management System (AMS). ISO55001:2014 specifies the requirements for an AMS, including artefacts such as the Strategic Asset Management Plan and Asset Management Plans. These artefacts are based on, and contain, technical and non-technical information that are inevitably linked in a complex manner. The complexity of connected information presents a significant challenge for organisations attempting to develop and manage an AMS and associated artefacts to meet the requirements of ISO55001:2014 and move beyond them towards AM best practice.

As demonstrated in other sectors, the model-based approach to AM in rail moves the development and management of an AMS from a document focus to an information focus. This provides a platform that can be a single source of information regarding the AMS and can output the required artefacts as needed. Having a single information repository creates a 'current common understanding' across the organisation in addition to other benefits, including: removal of duplicated information; efficient configuration management; and greater monitoring of the AMS.

A model-based AMS allows traceability from organisational objectives, to asset management objectives, to asset strategies, through to operational and maintenance activities. Other elements of the AMS, including risk management, decision management, organisational structure and roles, competency management, and performance management can be similarly traced. Additionally, the requirements of ISO55001:2014, and other relevant standards and regulations can be modelled and linked to the elements of the AMS that satisfy each requirement. A traceability report can be produced to show how the various elements of the AMS are linked to achieve the organisational objectives and compliance of the AMS to these standards.

INTRODUCTION

What is Asset Management?

Overview

Asset management is defined as 'the coordinated activity of an organisation to realise value from assets' (ISO55000:2014). This 'value realisation' concept is a fundamental principle of asset management and means that it is relevant to all types of organisations, whether they are large, small, private, public, government or not-for-profit (The Institute of Asset Management, 2015). Beyond the basic definition of asset management, it can be difficult for those new to the subject to understand exactly what asset management comprises. Fortunately, several conceptual models have been developed which provide a consolidated view of asset management including models from the Institute of Asset Management (Figure 1) and the Asset Management Council (Figure 2 over). These concept models also reflect what the Management System looks like to perform asset management within an organisation – this 'management system for asset management' is referred to as the Asset Management System (AMS).

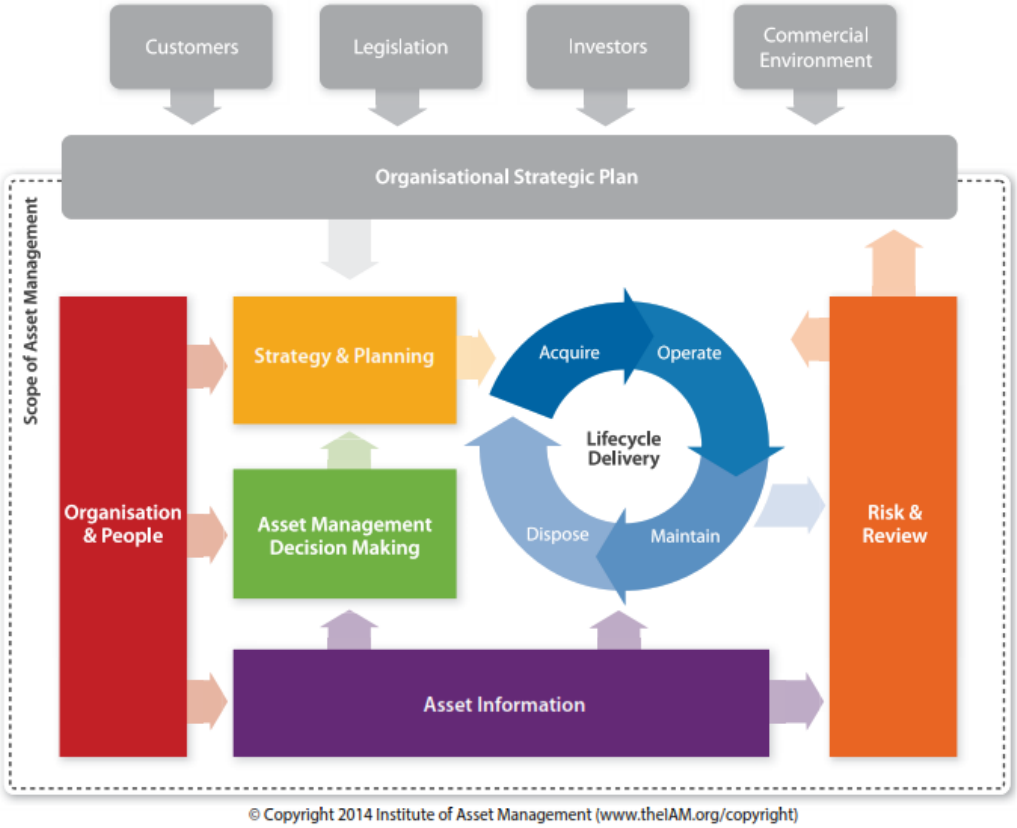

Figure 1. Scope of Asset Management (Institute of Asset Management)

Regardless of the number of definitions, views and applications of asset management, the core principles remain consistent: best practice asset management is, and (arguably) always has been, focussed on realising value from assets in a manner consistent with the mission and objectives of the organisation.

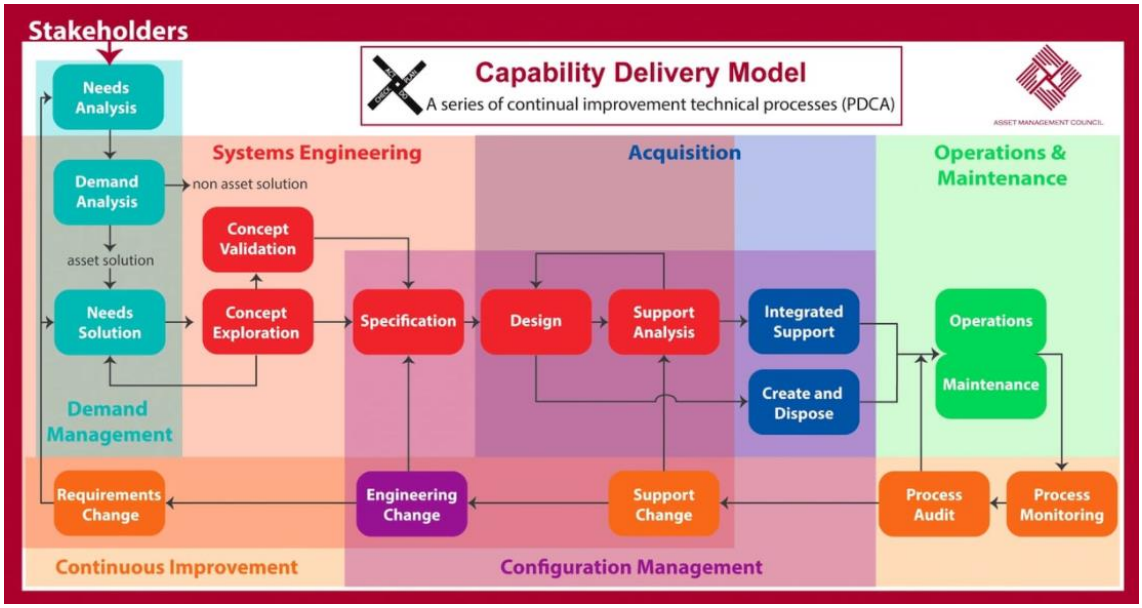

Figure 1. Capability Delivery Model (Asset Management Council)

Value

As already introduced, the role of asset management in an organisation is to realise maximum value from its assets, where the term 'value' is very much context-specific and defined by the organisation itself. Ideally the definition of value should be derived from an organisations mission and objectives. In some contexts, value can be simply equated to profit, but this is not the case for many organisations in the rail industry, particularly government organisations. Asset management for railway infrastructure is fundamentally about delivering outputs valued by customers, funders and other key stakeholders, in a sustainable way, for the lowest lifecycle cost (UIC, 2010).

ISO55001

The international standard for asset management ISO55001:2014 specifies the requirements for an AMS, including artefacts such as the Strategic Asset Management Plan (SAMP) and Asset Management Plans (AMPs). These artefacts are based on, and contain, technical and non-technical information from a variety of sources that are inevitably linked in a complex manner. ISO55001:2014 documents a comprehensive set of high-level requirements but does not set out to provide guidance on the actual implementation of an AMS (to some degree this is provided in ISO55002:2014). Just as each organisation is different, so too should be their AMS. This uniqueness coupled with the lack of implementation guidance creates a range of implementation challenges for organisations that desire a best practice AMS.

Implementation challenges

The challenges faced with implementation of a successful AMS are varied and extend from leadership buy-in to software configuration. From a technical perspective, the challenges include: various sources of information; high degree of information complexity; handling of graphical assets vs asset classes; and heavy reliance on documentation. Additionally, there are cultural challenges that include: management of change; rationale for decision making; and individual commitment at all levels of the organisation.

Asset management information has a high degree of complexity due to the connectedness of the information from various areas of the organisation. For example, an asset will relate to: operational information and processes, maintenance information and processes, roles and responsibilities of individuals, organisational goals; and a variety of documentation from data sheets to policies. The number of information links relevant to an AMS grows exponentially with organisational complexity and soon becomes impossible to manage using traditional documentation-based approaches.

For many organisations, especially in the rail industry, assets have multiple strategies that affect the way that they are operated and maintained based separately on their geographical location and their asset class. For example, wayside equipment will likely have a common strategy with respect to their maintenance, but this may need to be tailored depending on the required availability and reliability of the equipment. These differences are a result of differing objectives of geographical-based or network-based asset groups. For example, heavily used city rail networks will likely require a different level of maintainability than the same physical asset in a low use country line.

Despite the move towards data driven organisations, the reliance on documentation remains high. This is particularly the case with descriptive information such as organisational objectives or maintenance strategies. Some aspects of asset management have undergone a transition to a data-centred world (such as maintenance work orders being planned, scheduled and completed in a Computerised Maintenance Management System or CMMS). However, the uniqueness of how organisations capture, analyse and report on descriptive information has stalled this transition for descriptive data.

What is MBSE?

Overview

Model-Based Systems Engineering (MBSE) is the formalised application of modelling to support system requirements, design, analysis, verification and validation activities (INCOSE 2015). MBSE methodologies enable the capture of descriptive and analytical data into a model (or models) that provide traceability to rationale for the inclusion and quality of the data.

Benefits

Systems engineering and specifically MBSE has been successfully used in the aerospace and defence industries for decades. There are clear advantages in the use of MBSE through the project lifecycle in a variety of industries (Cook & Wilson, 2015). It is estimated that MBSE provides an additional 13% cost saving over good practice systems engineering through the lifecycle of a system (Cook & Wilson 2015). These savings are possible due to the additional benefits that MBSE provides over traditional systems engineering, including: defining a structured way to collect data; providing traceability between data elements and sources; promoting information-centric rather than document-centric design; enabling more effective configuration management; and creating a current common understanding of the system.

Traceability within models allows for the ability to connect information that may otherwise only be connected through corporate knowledge. For example, the development of an organisation's asset management policy and asset management objectives should be based on the organisation's mission and objectives (ISO55001:2014). MBSE methods and tools allow for such traceability to exist from system mission right through component functions and requirements.

MBSE shifts the focus of system design from document-centric to information-centric. This is achieved through the fundamental aspect of MBSE methodology which is that the model is the repository of information and documents are an output of this repository. This allows for a greater focus on information quality and consistency rather than document creation and formatting.

The term 'current common understanding' is often used to describe the organisational awareness that results from the application of MBSE during the early phases of the project lifecycle, where all information within the boundary of connected systems can be found in one place. Ensuring a 'current common understanding' of an organisational AMS is just as important but is difficult to achieve using a document-centric approach.

APPROACH

The problem

This paper outlines research into the challenges associated with implementing an AMS compliant with ISO55000 and explores whether the benefits of using an MBSE approach could assist in overcoming these challenges.

The intended output of the research is a framework which can be used to capture an organisation's asset management information and from this produce a suite of artefacts including (but not limited to): an asset management policy; a SAMP; AMPs; role descriptions; and an asset management maturity assessment. This framework (tools and a methodology) aims to address barriers that organisations face in the development and execution of an effective AMS. Benefits of such a framework include: reduction in resource required to develop and maintain the AMS; developing a clearer and more holistic understanding of asset management within an organisation; and production of artefacts that are not only compliant with ISO55001 and internally consistent but move an organisation towards best practice asset management.

Guidance

The development of the AMS framework was guided by several published documents from organisations including: International Standards Organisation, the Asset Management Council; the Institute of Asset Management; and the International Union of Railways (UIC).

The ISO55001 standard serves as the primary basis for defining the requirements of an AMS, and hence this was a significant resource for developing the requirements of the AMS framework. These requirements both guide the framework and form a part of the framework to inform the development of an organisations' AMS. The development of the framework has ensured that all requirements in ISO55001:2014 can be met. These requirements are individually populated in the framework, ready to be either linked to organisation specific information that satisfies the requirements or flagged as a gap in the organisations AMS.

Guidance documentation from the Asset Management Council and the Institute of Asset Management has formed the basis of the structuring of the framework to be able to develop an AMS that can achieve best practice asset management, above and beyond compliance with ISO55001.

The UIC has produced a series of documents that contextualise the ISO55000 series of standards and other asset management guidance for the rail industry. It is essential to note that the core principals and purpose of asset management is the same for all industries, but there are specific aspects of the rail industry that has led to tailoring of the framework to meet their needs. One such element is the handling of fixed vs moving assets across different geographical asset groups and asset classes. One challenge encountered in developing the AMS framework has been the consolidation of the guidance documentation (*see 'References' section*) into a clear view of what asset management means to the rail industry. This consolidation effort, coupled with the desired outcomes of the framework development has led to a series of outputs, which has been used to guide the development of the AMS framework and its supporting documentation.

Research outputs

For the AMS framework to be able to achieve its goal (*see 'The problem' section*), there are a series of outputs that are required to form the framework and support its use. These outputs include: a concept map describing the scope of an AMS in the rail context; a template MBSE model that includes a schema, templated information and output capability; a methodology and modelling guidance for the use of the framework; a suite of document templates that will be populated by model information; and an improvement and configuration management plan for the continuous development of the framework.

The AMS concept map is based on the guidance from the Asset Management Council, the Institute of Asset Management and UIC. This map shows the major components of an AMS that are required to execute best practice asset management. It is important to note that this map (see Figure 2) can be tailored for each organisation but aims to capture the entirety of an AMS in any rail context.

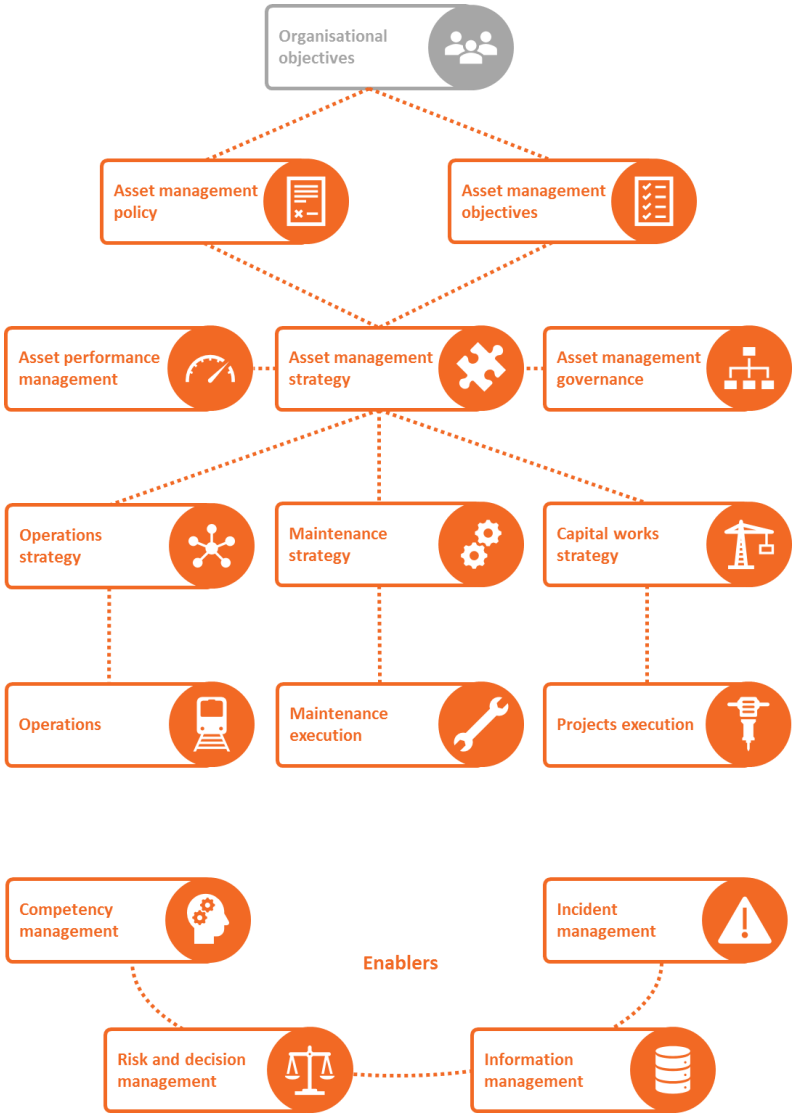

Figure 2. AMS concept map

A template MBSE model has being created based on this concept map of an AMS and other relevant guidance. This model includes: a defined schema for the structure of information; template content that can be tailored to the organisation; and output scripts that produce the required AMS artefacts. The schema is a tailorable information structure that determines the type of information required and how the various entity types can be linked to form a useful collection of information that describes the AMS of the organisation. Templated content is used as a starting point for information that is common to all organisations. This enables information relationships to be pre-populated, streamlining the modelling effort. Output scripts are used to collect and structure the model content into human-readable artefacts that define various aspects of the AMS (more information on these are detailed in the 'Framework outputs' section).

A description of the methodology and modelling guidance will be developed to guide organisations and the modelling team in the gathering, analysis and modelling of information for the AMS development. This guidance will include how to interact with the framework and how to tailor it for the unique needs of each organisation. Similarly, document templates will be created based on guidance from the Asset Management Council and the Institute of Asset Management that will display the information from the model. These documents are intended to: display the information in the model in a human-readable form; be used as effective AMS communication tools; and ensure the AMS is compliant to ISO55001.

PROPOSED APPLICATION

Process for using the framework

A structured process is being developed which forms the basis for the methodology and modelling guidance. This process includes a methodology for the continuous improvement of the AMS as depicted in Figure 3. This includes: an initial capture of the organisations AMS; an asset management maturity assessment; an analysis of changes that need to be made to the AMS (gap analysis); an action plan for closing the gaps; and the execution of the action plan and subsequent AMS model update.

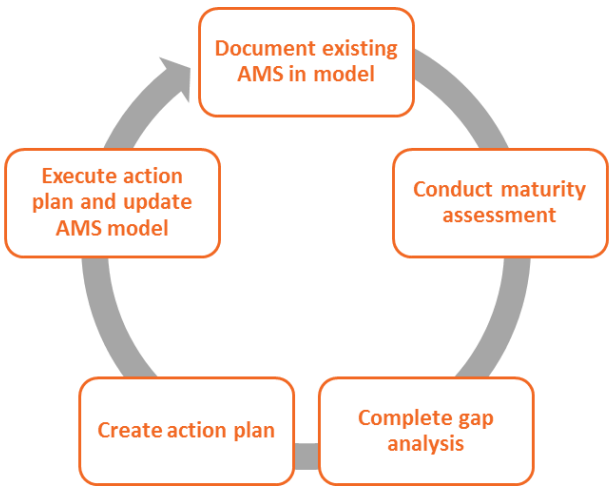

Figure 3. AMS model continuous development process

The initial documentation of the AMS will form the basis for the first set of model outputs (detailed in the 'Framework outputs' section). As the AMS undergoes development and improvement, these outputs can be regenerated with the updated information, while retaining the model as the current common

understanding of the organisations AMS. The documents are then a reflection of this understanding that is scope limited based on the purpose of the documentation. For example, an AMP for a specific line will reflect the information in the model that is relevant to that line and appropriate for the contents of an AMP.

Inputs

The proposed use of the AMS framework starts with the input of organisation data that form the foundation of the AMS. This information includes: organisational information such as roles and structure; organisational and asset management objectives; guiding documentation such as external and organisational standards; identification of AMS stakeholders and their expectations; physical asset information; business processes; and organisation context information such as economic risks.

Organisational information is required in the AMS model as this defines the structure and roles that will be responsible for undertaking the various AMS functions. The organisational information required includes organisational structure, roles and responsibilities. Organisational and asset management objectives are the basis of all other information in the AMS model. As such, these elements in the model are referenced by all other elements through a series of logical relationships.

Guiding documentation is essential in an effective and auditable AMS. The guidance documentation along with the objectives provide the justification for all elements within the AMS model and are the rationale for all functions that an AMS performs. These guidance documents can include: international or industry standards; organisational standards and policies; management directives; organisational promises; and any other official guidance that provides direction for how the AMS is to be developed and/or executed.

Identification of stakeholders and their expectations is essential to any AMS. It is the stakeholders that define how value is determined by the organisation and value is the aim of asset management. In the AMS model, stakeholders are defined, along with their expectations, which form guidance for the AMS model information.

Physical asset information is essential as it is the physical assets that provide the value to the organisation. This information can be linked to the roles that are responsible for the assets and the actions that are performed on the asset through operations, maintenance, projects and governance activities. Not all asset information is required in the AMS model, but a sufficient level of detail is required to enable asset management planning. For example, specifics of an asset datasheet may not be required, but the total hours required to maintain an asset is required for the planning and budgeting efforts.

Business processes are also captured and stored in the model and related to information such as roles that perform them, requirements that define them, and the elements of the AMS that govern them. This allows for a holistic view of why the process is being performed, how it is being performed and who is performing it.

Organisational context information is very important to the development and execution of an AMS. Organisations do not exist in a vacuum, there are always external factors that can affect the objectives of an organisation and the way that the organisation achieves those objectives. This analysis of external factors may lead to risks and issues that require resolution by the AMS.

Framework outputs

Compliance with ISO55001:2014

With AMS information contained in the model, a suite of documents can now be generated. These documents can be tailored based on the uniqueness of the organisation and can be used to meet objectives

such as ISO55001 compliance. These documents include (but are not limited to): an asset management policy; a SAMP; various AMPs; Asset Management System Plans (AMSPs); Responsible-Accountable-Consulted-Informed (RACI) charts; traceability reports; and asset management maturity assessments.

The asset management policy is a high-level document designed to define and commit an organisation to good practice asset management (UIC 2016). The information, or policy statements, that form the bulk of this document are stored in the model and can be consolidated with other organisational information to form the policy.

The SAMP is a document required by ISO55001:2014 that defines the role of the AMS in the organisation and how it is used to achieve the organisational objectives (ISO55001:2014). This document can be generated by the model using a variety of information based on the SAMP template, but tailorable to the needs of the organisation.

AMPs are required by ISO55001:2014 and define the planning of asset management activities including: financial considerations; resourcing for asset management activities; and other required support functions (ISO55001:2014). These documents can be generated by the model based on a variety of information that is linked specifically to the asset (geographical or asset class) that scopes the AMP.

AMSPs are not defined in ISO55001:2014 but are used in this context to capture information related to significant updates to the AMS. What the AMP is for asset groups and classes, the AMSPs are for AMS elements. These documents can be generated by the model based on the risks, issues and actions identified in the AMS model that link to the specific AMS element that scopes the AMSP.

RACI chart(s) are useful in communication of responsibilities of roles in an asset management context. These can be generated by the model based on the allocation of roles to asset management functions and actions as defined in the AMS model. Additionally, role descriptions can also be generated using the same source data.

Traceability reports allow for a clear linkage between elements within the model. In MBSE, these types of reports can be used for a variety of reasons including traceability of system functions and components to originating requirements or needs. In the AMS model, there are two primary traceability reports that will be used: entity links to organisational objectives; and ISO55001 compliance. The entity links to organisational objects will display how any given entity relates to one or more organisational objectives through a series of model relationships. This allows for any activity, role, action or asset to be justified and rationalised. The ISO55001 compliance report will display how each requirement of ISO55001 is met by the AMS and the specific AMS components, functions or other elements and relationships that satisfy it.

Moving beyond compliance

Asset management maturity assessments are a structured way to determine the maturity of the asset management of an organisation by analysing specific subject areas on a defined scale. This assessment criteria forms part of the AMS model and the assessment is an important part of the process for developing the model (see 'Process for using the framework' section). Using this information, an output can be generated that details the maturity assessment of the organisation, the risks that were raised from the assessment, and the planned actions to address these risks.

In addition, further traceability reports are possible with the information in the model. For example, a traceability report displaying AMS compliance with Office of National Rail Safety Regulator (ONRSR) requirements could be produced from the model and would offer significant benefits to any Australian rail organisation.

INITIAL FINDINGS

The research presented in this paper has achieved the following: the successful creation of a relationship structure that links all elements of an AMS to organisational objectives; early stage validation that all requirements of ISO55001:2014 are supported by one or more elements or relationships in the model; and early stage testing that shows the use of a thin thread approach can streamline the capture and analysis of information in the model. Although the approach is yet to be tested in an operating organisation, these findings suggest the AMS framework will be successful.

The linking of all AMS elements to organisational objectives is a significant leap forward in the implementation of an AMS. These relationships are stored in one model that shows the current common understanding of the AMS and traceability reports can be produced to show these relationships. In a conventional (document-based) AMS implementation, finding these relationships is laborious at best and often impossible. This attribute of the framework shines light on the 'why' for all elements of the AMS.

The authors of this paper have stepped through all requirements in ISO55001:2014 to ensure that demonstration of compliance is possible through the model. This may be through the model structure, entities or relationships. This attribute of the framework provides confidence that an organisation can be ISO55001:2014 compliant, and this compliance can be demonstrated through the production of a traceability report.

Streamlining the capture and analysis of information is an important aspect of any management system implementation. The AMS model does not have a beginning and end like a document does. This enables information to be captured in the order that makes the most sense to the organisation and their situation. Using a thin thread approach allows the model to be populated with high level detail that covers all aspects of the AMS, and dive into detail when appropriate.

These initial findings will be further validated as research work progresses and further testing of the framework is conducted.

FURTHER WORK

The next major milestone for this work will be to populate and test the framework for a rail organisation. This will serve to challenge the assumptions made in the development of the framework and to collect lessons learned for its future development. Additionally, this will enable the tailoring process to be tested and ensure that the framework is flexible enough to meet the organisation's needs.

Following a test of the framework in a rail organisation, it will be further developed to incorporate the lessons learned. This process will be repeated through use and development cycles according to the improvement and configuration management plan.

Given that asset management principles are applicable to any business model based on extracting value from assets, it is the view of the authors that the framework could be further developed for use in other business sectors. This would require tailoring several aspects of the model structure that have been designed specifically with rail in mind.

The authors anticipate that this further work will lead the way for a 'next generation' Asset Management System that is inherently model-based. Just as maintenance execution has now moved from paper-based to data-based through the development of CMMS tools, so too will the fundamental aspects of good practice asset management (strategy, policy, processes etc) move away from paper-based to a structured, logical information model.

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BIOGRAPHIES

Bradley Hocking is a professional engineer with experience in asset management, systems engineering, reliability engineering and risk management. He is an honours graduate of the University of Adelaide, an Associate Systems Engineering Professional and a certified member of the Society for Maintenance and Reliability Professionals. As a Systems Engineer, Bradley has gained experience in model-based systems engineering through his contribution to projects across various industries.

Chris Sproston is a chartered professional engineer with more than 15 years' experience in asset management covering a range of disciplines, including systems engineering, reliability engineering, maintenance management, process safety, risk management and business process improvement. Chris holds an honours degree in mechanical engineering from Loughborough University in the UK and is a member of Engineers Australia.

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