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Digital Asset Information Management for Transport Infrastructure: Framework and Implementation

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Abstract. Asset management is the systematic process of deploying, operating, maintaining, upgrading and disposing of built environment assets. Effective asset management requires the involvement of all levels of an organisation in planning, control and monitoring of asset performance that combines management, financial, economic and other activities and practices. This paper aims to propose and evaluate a framework for digital asset information management, including four four elements – data exchange, classification system, location referencing and information requirement. This framework is validated through interviews with a road agency in Australia. It is expected that this framework is useful for road agencies to evaluate their current practices and take appropriate actions towards digital asset information management.

Keywords: Digital engineering, asset management, information management, location referencing.

1 Introduction

An infrastructure asset requires a large capital investment and then requires ongoing operation and maintenance, including improvement and removal of roads. The Australian Government spends more than AUD$7 billion every year on maintaining and renewing roads [1]. Maintenance of a road consists of routine maintenance, specific maintenance, restoration maintenance and pavement rehabilitation, all of which have a crucial influence on the related economic, social and environmental aspects.

Asset management is the entire process of planning, programming, and systematically monitoring an asset. Asset management decisions, such as data-supported decision-making, management systems, relationships between condition and performance, and trade-off and investment analysis are integral components of daily business that support the mission to meet the service requirements of assets.

In recent years, while Building Information Modelling has become an important strategy in building, construction and infrastructure sectors to improve productivity and health and safety, the use of BIM for asset management has only been recognised recently in terms of its benefits of managing assets when using 3D models. Building Information Modelling (BIM) is an intelligent 3D model-based process to inform and communicate project decisions and communicate project decisions [2]. BIM is a term with three linked functions, including Building Information Modelling, Building Information Model and Building Information Management [3]. Building Information Modelling refers to the business process of generating and using building data in the lifecycle of buildings. Building Information Model refers to the digital representation of the physical and functional characteristics of a facility and Building Information Management is the process of utilizing digital building information for effective sharing. BIM and asset information can work together to make informed decisions in areas such as bringing existing assets into BIM, developing new assets in BIM, operating and managing existing or new assets.

This paper therefore aims to develop a digital asset information management framework so that BIM or other digital engineering technologies can be utilized for effective asset management decisions.

2 Digital asset information management

A review of exisiting standards and current practices reveals the importance of the below four elements in digital asset information management.

2.1 Data exchange

Digital asset information model is dependent on strong information and data exchange capabilities, allowing interoperability of information generated throughout the project lifecycle. Over the past few years, a few data exchange standars for transport infrastructure have been developed.

Land and Infrastructure Conceptual Model Standard (LandInfra) is an Open Geispatial Consortium (OGC) standard which defines concepts for providing and under-standing information about land and civil engineering infrastructure facilities [4]. The concepts in LandInfra are formally using case driven subset of LandXML functionality, but supported by a UML (Unified Modeling Language) diagrams. Additionally, the standard covers various subject areas defined by so called Requirement Classes (RCs), which mandate what the subsequent encodings must support in order to claim conformance to LandInfra. Each requirement class (RC) in RCs has a corresponding Conformance Class which explains how the encoding is to be tested for conformance.

In addition, the extension project of "IFC for Infrastructure" provides the data model for 3D and 2D alignment information mainly for spatial location of infrastructure assets and further being a baseline for projects like IFC-Bridge and IFC-Road [5]. For example, the main scope of the IFC Road project is to extend product data model of road facilities with earthwork enabling open data access based on IFC4 (ISO16739) schema in order to secure interoperability in delivering the as-built design model to government. The data schema of IFC-road includes spatial structure, physical structure, properties and earthwork model.

2.2 Asset classification

In the field of asset management, hierarchical classification of transportation assets is normally used. For example, the Department of Transport in NSW, Australia adopts a four-level classification system, including asset discipline (Level 1; refers to asset disciplines together with the related asset classes, e.g. architecture & service, civil & structures, electrical, fleet, property, signalling & control, technology & telecommunications, and track), asset class (Level 2; refers to asset classes and descriptions together with related asset functions for each asset class), asset function (Level 3; refers to asset functions and descriptions relevant for an asset class, such as Complexes, e.g. road carriageway, waterway, bus fleet depot, quarry and land, Entities e.g. building, footbridge, sea wall, jetty, bus and furry, Systems, e.g. air supply system and LV lighting system, and Products, e.g. air dryers and meters) and asset type (Level 4; refers to asset types and descriptions relevant for an asset function).

On the other hand, Roads and Maritime Services in NSW adopts a six-level asset classification system, including asset group, asset class, asset function, asset type, asset component and asset sub-component. In addition, Austroads is undertaking an ambitious project to establish a harmonised road asset data standard for use in Australia and New Zealand. The Road Metadata Standard Project has been initiated in response to requests from stakeholders who increasingly need to share data with other road management agencies but are frustrated by the lack of common data standards [6]. This project is an on-going project at the time of this study.

2.3 Location referencing

Austroads investigate the potential to harmonise road location referencing and identify a feasible approach to harmonisation of road location referencing. It is discovered that when conducting a data collection survey on the network, it is important that the data is properly referenced and that location can be assigned repeatedly over time with a level of confidence. Without proper location referencing, users would have no way of discerning at what location the data was collected, severely limiting the use of the data. Generally, the location referencing methods adopted by Austroads member authorities can be separated into the two major categories:

- Linear referencing defines a location in terms of distance and direction in reference to another location (e.g. 15 km east of location X). Linear referencing is limited to a start and end reference point and is directly related to its geographical location.
- Spatial referencing defines a location using a set of coordinates, which describes a location in two or three dimensions, calculated using a mathematical model of the earth, where all locations are referenced to the same point or against a datum.

Currently, most transportation authorities use linear referencing methods as their primary means of referencing locations within their network. These methods are simple to understand; however, they incur high installation and maintenance costs in order for them to be an effective referencing tool and they are a relative referencing tool because the physical markers used as reference points may change over time as the network is altered.

A move to spatial referencing as the main method of location referencing asset data is anticipated. Given the current issues and constraints associated with spatial location referencing, a new spatial approach to location referencing is likely to require some years to develop and to integrate as each member authority develops and acquires an accurate spatial representation of its centrelines. Over time this technology will become common among all member authorities, and new spatial referencing methods and systems may be adopted as a standard for field location referencing.

2.4 Information requirement

To enable the owner to safely and effectively operate new assets and refurbished assets, asset information requirements need to be stated clearly before construction commences so as to define the responsibility of transferring the data between organisations.

Prior asset handover and asset acceptance phase, asset information requirements shall be collected and managed at the stage of plan and acquire. Providing and updating the following detailed asset information requirements facilitates assert handover, commissioning, operation and maintenance.

The below example shows the information requirement of an infrastructure asset's life cycle. At the commencement phase, asset information linked to requirements specification, feasibility, environmental, geotechnical reliability, availability, maintainability and safety (RAMS), system safety assurance plan and hazard log, shall be recorded and submitted. In the operation and maintenance stage, configuration data (i.e. asset status), condition data (including asset condition, assessment criteria and remaining life), operational data (including asset criticality and assessment criteria, and asset utilisation and capacity), maintenance data (including maintenance activities data, preventive service schedule, work orders for maintenance activity, defects, work breakdown structures, etc.) and other finaicial data and documents should be recorded.

2.5 The framework

A digital asset information model for transport infrastructure is therefore proposed based on the above review of literature and standards. The model includes the aforementioned four main modules.

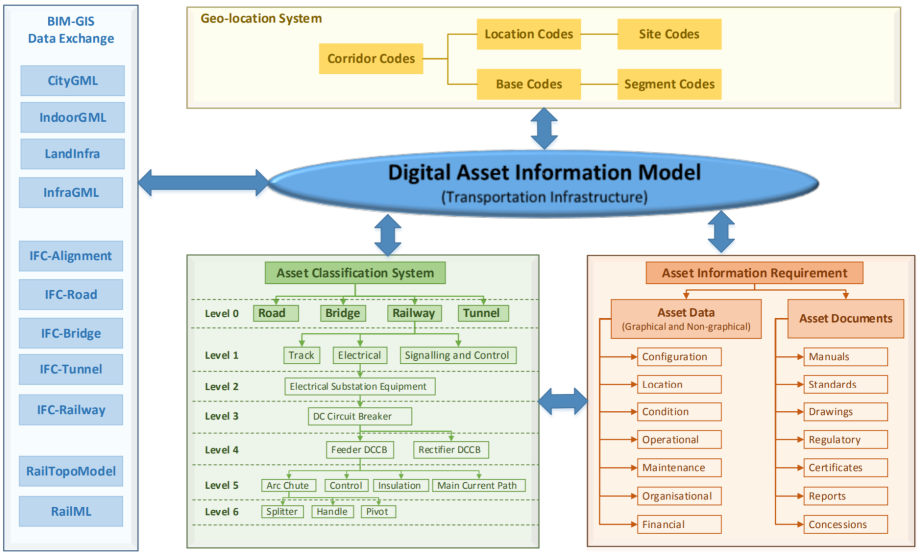

Fig. 1. The digital asset information management framework

3 Case study

VicRoads is the Victorian Government's central road agency. Its purpose is to deliver social, economic and environmental benefits to communities throughout Victoria by managing the Victorian arterial road network and its use as an integral part of the overall transport system.

The aim of this case study was to: (1) understand VicRoads' current road asset operation and maintenance processes; (2) understand VicRoads' current asset management tools or platforms including their functions, data inputs and outputs, and underlying data schemas; and (3) benchmark VicRoads' road asset management practice in terms of digitalisation.

Document reviews and internal interviews and workshops were conducted to help the team understand VicRoads' current asset management practices. Collected documents included VicRoads organisation chart, design and construction specifications, asset management documents, including, pavement, street lighting, intelligent traffic system and bridges, as well as road design publications and standards. Asset management tools and platforms used in VicRoads, including RAI (Road Asset Inventory) system, SCATS (Sydney Coordinated Adaptive Traffic System), STREAMS (an international award-winning Intelligent Transport System (ITS) that supports road authorities to help save lives, reduce congestion and make road networks safer), AMCS (Asset Monitoring and Control System), Connect (financial System, formerly known as PARMS) and RAS (Road Asset System) were also reviewed. Focus group study was conducted with the participants from five four departments within VicRoads, including asset management team, delivery team, network design services team and asset services team.

3.1 Current practices

Asset Classification. In 2018, VicRoads developed a new Asset Hierarchy in order to meet the requirements of the new enterprise asset management system version (i.e. Ellipse 6.3) whilst still supporting the essential processes of existing Connect system (formerly known as PARMS-Program and Resource Management System). The new Asset Hierarchy contains three main types of sub-hierarchies: Road Asset Hierarchy, Structures Asset Hierarchy and Electrical/Communications Asset Hierarchy.

Figure 2 shows an example of the Road Asset Hierarchy. The new Hierarchy recognises the existing equipment classes in Connect and allows for the creation of additional records to support assets to be transferred from legacy systems. However, the new Asset Hierarchy can only be maintained, modified and extended by authorised asset managers using standard Connect user functions, which means it cannot be shared and used by other internal Asset Management Tools such as RAI, SCATS, STREAMS and AMCS. Indeed, each tool has its own asset hierarchy to support asset information storage. Therefore, VicRoads Asset Management team needs to maintain at least five different types of asset hierarchies. The lack of a unified Asset Hierarchy increases the difficulty and complexity of asset information capturing, updating and validation. In addition, automated asset data sharing and exchanging among the various asset management systems and platforms becomes impossible.

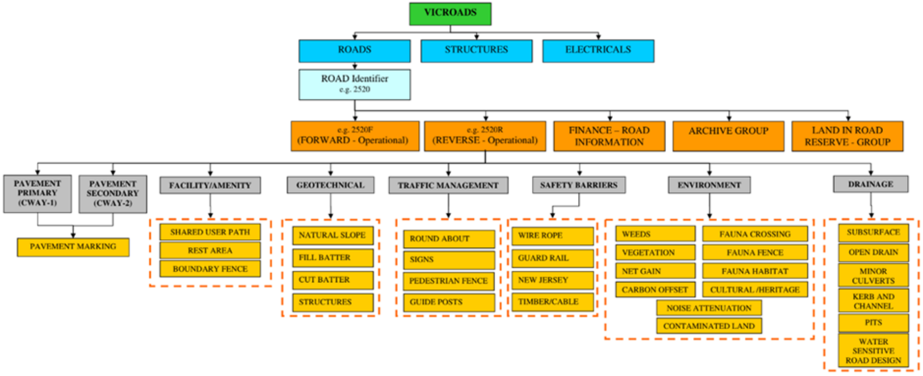

Fig. 2. Road asset hierarchy

Location Referencing. Currently, the asset location referencing used is the VicRoads' Standard Road Referencing System (SRRS), which comprises a database model of the declared road network, defined by links joining physical reference markers and fixed features of known and measured locations. The location of any point on the network may then be defined by measured distances along the link relative to a physical reference marker or fixed feature.

The SRRS is a linear referencing method which can be communicated concisely via plaintext. However, a major limitation of linear referencing is that specifying points that are not on a linear feature is troublesome and error-prone, though not entirely impossible. In addition, for the use of linear referencing, the starting points and end points should be well defined, which can be difficult in some cases [7]. For example, if intersection points are used as starting and end points for roads, problems may be created for complex intersections.

Tools and Platforms. In VicRoads, six main systems and/or tools are currently utilised to support asset operation and maintenance: RAI, SCATS, STREAMS, AMCS, RAS and spreadsheets for structures and road assets.

RAI is a powerful system, providing fast and efficient filtering and searching utilities, enabling staff members to easily locate asset records. RAI provides the ability for VicRoads to:

- record inventory information regarding electrical, communications, operating systems;
- associate incident and traffic management, and traffic control assets for the full lifecycle of the asset;
- record and track maintenance jobs for each asset;
- record and track jobs relating to faults for each asset and their rectification;
- allocate to, and notify contractors of, jobs for their attention; and
- produce various reports on the assets and jobs.

SCATS is an adaptive urban traffic management system that synchronises traffic signals to optimise traffic flow across a whole city, region or corridor.

STREAMS is an international Intelligent Transport System (ITS) that supports road authorities to help save lives, reduce congestion and make road networks safer. It enables road authorities to manage their transport network holistically, rather than as a collection of separate components.

AMCS is a smart street lighting management system that improves safety and security through improved visibility, saves money by consuming less electricity and has a positive impact on the environment due to the increased life expectancy of LED luminaires.

It should be noted that these four systems normally work independently. Although there are a few connections built between RAI and SCATS, data searching and sharing across these four systems are difficult and time-consuming. Currently, VicRoads is developing a new platform, vMap, to address this issue. vMap is a one-stop-shop for all spatial data. It contains information from a variety of different data sources around VicRoads including assets, road networks, strategic and planning data, and road safety.

3.2 Recommendations

As a result of the benchmarking activity, three early recommendations are proposed to facilitate the transformation from VicRoads' current asset management practice towards the ideal DAIM paradigm.

Recommendation 1: Develop a unified asset classification/hierarchy system and apply it to all the internal asset management systems/platforms.

The aim of the unified asset classification/hierarchy system is to provide a single point of reference for asset owners and operators. Four existing asset classification/hierarchy systems, developed by Transport for NSW, NSW Roads and Maritime Services, Austroads and One Network Road Classification (ONRC), can be used as a basis.

Recommendation 2: Move from a Linear Referencing System (i.e. 1D) to a Spatial Referencing System (i.e. 2D or 3D).

Given the limitations of the Linear Referencing System, Spatial Referencing Systems such as Geospatial Referencing Systems (2D) and Geometric Referencing Systems (2D or 3D) should be applied. The former one provides a way to describe locations on the earth's surface in real-world coordinates. This includes GIS as well as coordinate-based mapping systems. Searching and mapping are two key advantages of this referencing system. Most governments rely heavily on GIS applications for managing geographic data. These provide searching (proximity-based) and modelling abilities. The latter is based on digital models that provide coordinate geometry within local model coordinates. Typically, these include digital design (2D or 3D) and BIM models. Some model environments are stand-alone and, more recently, they may be geo-connected (placed in the real world). The family of geometric reference systems are those based on geometric models of infrastructure.

Recommendation 3: Apply BIM and other Digital Engineering technologies in future projects.

Digital Engineering or BIM, is much more than developing static models. It can facilitate harnessing the true potential of the built environment industry and creating a platform for multiple applications by integrating digitisation and GIS [8]. In addition, as-built BIM models can accelerate the information handover phase and improve asset data quality in terms of accuracy, integrity and consistency. BIM processes are commonly adopted in either building or infrastructure projects. Other emerging technologies, such as laser survey techniques, have also been employed. Over the next decade, BIM and digital engineering technologies that combine internet of things, data analytics and optimization will enable asset owners to make informed decisions in the asset planning and management areas.

4 Conclusions

A comprehensive review of digital asset management practices, including asset data exchange, asset classification, asset location referencing and asset information requirements is conducted and validated through a case study. The results suggestion that asset management processes and outcomes over the facility lifecycle can be improved using the framework. At an organisational level, large companies are well advised to develop their own digital transformation strategies to facilitate digital asset information management.

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