Location definition for road asset management systems: case of Sarawak Public Works Department

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Abstract. Sarawak Public Works Department will be expected, in the near future, to change the way their road assets are designed, constructed and managed. Currently, there is a need to identify how road asset information is being collected, stored and retrieved. Location definition is an attribute that provides a simple framework for the identification of current technical requirements to exchange information within the relevant road asset management system. The balance of this paper presents an overview of the current road asset management systems and their location definition. The findings are results of the analysis of asset management systems and standards as well as the verbal engagement with PWD Sarawak experts in this field. The findings suggest that emerging systems and processes are moving from solely linear referenced models towards incorporating geospatial location data at different dimensional levels. Given this evolution, in this paper, road asset management systems are classified into three location definition categories considering their location referencing methods and their levels of dimensional detail. However, further research is required within PWD Sarawak to identify required location referencing in order to improve automation of the information exchange between the emerging BIM models, geospatial systems and the automated data collection tools.

1. Introduction

Under the Sarawak Socio-Economic Transformation Plan (SETP), road construction in Sarawak is of great importance [1]. Sarawak has set a target of a highly connected road network by 2030 [2]. While many initiatives have been implemented to accelerate the state growth, more are in the planning stage. Examples include several road developments such as the Pan Borneo Highway Phase 1/2 and Sarawak Coastal Highways, bridges including ASEAN, Batang Lupal and Batang Rambungan as well as future rail developments such as Kuching Light Rail Transit (LRT). To assist in meeting this target, a more complex integrated digital engineering system is being considered to improve the information exchange and interoperability between asset management systems, models and tools [3].

The adoption of Building Information Modelling (BIM) in Malaysia was primarily promoted by the private sector in early 2000 [4]. However, BIM has only become a popular term when Public Works Department (PWD) introduced BIM in construction planning for public buildings in 2007 through their BIM Manual and Guidelines [5]. PWD which is the largest technical department under the Ministry of Works Malaysia (MOW), is responsible for all design, planning, construction, development and maintenance of public infrastructure and government buildings in Malaysia.
In the past years, PWD together with the Construction Industry Development Board (CIDB) has formed the BIM Steering Committee, BIM Roadmap, and BIM Portal, involving policy makers, practitioners, and academicians [6]. While, there has been an increasingly demand for adoption of BIM for vertical construction, little emphasis has been placed on the adoption of digital engineering practices for horizontal infrastructure assets such as roads and rail.

### 1.1. Problem statement
Sarawak Public Works Department will be expected, in the near future, to change the way their road assets are designed, constructed and managed. Digital engineering practices in construction sector, such as Building Information Modelling (BIM) and Geographic Information System (GIS) will provide a new method for capturing and managing road asset information [7, 8].

The lifecycle information of road assets has generally been categorised differently within each functional unit [9]. Globally, road authorities have developed multiple units with multiple functional and technical information requirements. This silo of organisational structures within road authorities and their relevant stakeholders has been identified as a barrier to the integration and exchange of information between the lifecycle functions of road asset [10]. This is currently the case for Sarawak Public Works Department. Thus, the Sarawak Public Works Department has entered into a collaborative research project with Swinburne University of Technology, to identify current road asset lifecycle information requirements that could be changed to suit an integrated digital asset management system.

### 1.2. Research objective
Currently, there is a need to identify how road asset information is being collected, stored and retrieved. The first step is to gather information on current digital asset management systems and processes related to the road asset lifecycle information. This can be done by focusing on an attribute or a definition that could provide an indication of what lifecycle asset information has been or has not been exchanged or integrated into asset management systems.

Location definition is an attribute that provides a simple framework for the identification of the underlying information that is currently recorded and managed into the relevant asset management system. The aim of this research is to look into the digital engineering practices in road asset management systems of Sarawak Public Works Department from the lens of location definition. The findings of this exploration aim to present a location definition model that identify current technical information requirements that Sarawak Public Works Department needs to consider for having an integrated digital asset management system. Consequently, this emergent exploratory research revolves around the following question: to explore the location definition for management and integration of information in road asset management systems and processes of Sarawak Public Works Department

There has been an array of definitions within academic articles and industry documents for concepts and terms that are relevant to this research. However, the following definitions in the Table 1 are the most appropriate definitions for this research.

| Term                  | Definition                                                                 | Source |
|-----------------------|---------------------------------------------------------------------------|--------|
| Digital Engineering   | A collaborative way of working, using digital processes, to enable more productive methods of planning, designing, constructing, operating and maintaining built assets. | [11]   |
| BIM                   | Building information models (note models not modelling) are parametric and 3D objects that can be used as a shared knowledge resource by different stakeholders involved in lifecycle of a building or infrastructure asset. | [12]   |
Table 1. Definition of Key Terms and Concepts (continued)

| Term       | Definition                                                                                   | Reference |
|------------|----------------------------------------------------------------------------------------------|-----------|
| GIS        | A digital information system that is designed to work with data referenced by geographical coordinated-based features | [13]      |
| Object     | Any kind of object or structure which can reasonably be related to a geographical location, such as points of interest (POIs), roads, places, bridges, buildings or agricultural areas. | [14]      |
| Location   | A virtual object that is temporal, graphical and model-independent. The virtual object can be a point, line, path or area, representing a physical place on a road network. | [8]       |
| Location Definition | Identification of a location in terms of its level of dimension, position and geometry. | [15]      |

2. Research Approach
The methodology adopted in this qualitative research has been exploratory and emergent [16, 17]. At the core of this methodology, it was aimed to actively search for documents of digital systems or processes related to road asset lifecycle information [18]. The documents were analysed to identify their location definition and types of information which they contain of [19]. The documents were both in electronic and non-electronic format and included systems databases, guidelines, policies, design models, etc. The asset information were classified into structured data (e.g. relational databases), semi-structured data (e.g. spreadsheets), or non-structured data (e.g. images.sketches or maps) [20].

The analytical process has been inductive, with the aim of exploring location definition for various asset management system or process. This has involved in identifying the level of location dimension (e.g. point, polyline), position of a location with respect to other locations in the system/process as well as the geometry of location (e.g. straight line or horizontal/vertical curve). Table 2 shows an overview of the data collection methods and framework for data analysis in this study.

Table 2: Overview of Data Collection Methods

| Verbal Engagement | Written Documents |
|-------------------|-------------------|
| Verbal engagement with 25 expert informants in the area of Asset Management (AM), BIM and GIS | 24 Documents (e.g. manuals, standards, progress reports) Asset Management systems or processes |
| Sarawak Public Works Department-owned road assets | Location Definition |
| 6 internal branches BIM/GIS/AM | 1 project manager and 3 contractors |
| Level of Dimension | Position/Topology |
| Geometry |

3. Road Asset Management Systems
This section provides a summary of asset management systems and processes related to Sarawak PWD-owned road assets. These systems and processes are analysed for identifying their location definition and hence types of information which they record.

3.1. RMMS and MARRIS
The Road Maintenance Management System (RMMS) developed in 1987, is a general road maintenance system for Sarawak State roads. It is designed to manage and monitor concessionaires’ maintenance operations by implementing work methods and controlled maintenance expenditures. In the current version of Road Maintenance Management System (RMMS), pavement locations are recorded at every 100m chainage to report pavement attributes such as material, condition or any assigned maintenance activities by a road party. However, majority of non-movable assets such as road furniture, culvert,
bridges, riverine infrastructure, drainage and irrigation and others are still recorded using manual registers or spreadsheets. Several improvements have been considered for the new version of RMMS. Figure 1 shows some of the previous, current and proposed features.

Figure 1. The evolution of PWD Sarawak RMMS

In the current discussions within PWD Sarawak, it is evident that there is an increasing interest towards the use of Global Positioning System (GPS) coordinates tagging of bridges, culverts and road furniture on the road map, which can populate the existing GIS database. However, current or future systems do not yet capture geospatial polylines for pavements and other polygon assets such as drainage and slopes. On the other hand, the GIS unit in the organisation captures capture and record polyline and polygon geospatial locations for populating the condition data. The GIS database is also used for the purpose of reviewing the wayleave application from other infrastructure departments in Sarawak. Nevertheless, according to the expert informants, there is little integration between road asset management data and the geospatial system. Also, there is still no integration or information exchange between the GIS databases managed by Sarawak Land & Survey Department and other infrastructure departments.

Another system containing some pavement data is the Malaysian Road Record Information System (MARRIS) that is designed for accurate road length measurement and for eliminating double registration of State Roads, the Municipal Roads, the Rural Roads, Island Roads and the Village Roads. The system records the GPS coordinates of the start and ending points as well as the width of road carriageways, shoulders, drainage and roundabouts. The manual published by the Ministry of Finance specifies the reference points for the length and width measurements of single and dual carriageways, shoulders as well as the circumference of roundabout circles.

Considering the increasing capability of GPS and other remote sensing technologies and tools, road asset management systems have realized the benefits of GIS mapping of road assets. An example is a pilot Sarawak Integrated Asset Management System (IAMS) for 120km of Federal and State roads in Sarawak.

3.2. Pilot road asset management system

The pilot IAMS is designed to record and locate various features such as road pavement and road furniture using GPS coordinates via Radio Frequency Identification (RFID) System for road asset tracking. In addition, a Road Asset Condition Assessment System (RACAS), a data capturing system (HD camera, GPS, G-sensor) is adopted for capturing the pavement condition data which has been populated on a web-based GIS database management system (shown in Figure 2). Roads centreline
polylines and road furniture point assets are located with GPS coordinates which are then converted to PWD road chainage and road coding system.

**Figure 2.** Road Furniture GIS Mapping & Pavement Condition Captured by RACAS

IAMS and other individual systems, managed by road maintenance concessionaire in Sarawak, are influenced by digital systems such as RAMS (Road Asset Management System) developed for Toll Expressways in West Malaysia. RAMS is designed for creating a complete register of asset inventory, condition and work information for both discrete assets (e.g. bridge, slopes) and continuous assets (e.g. guardrails, pavements). Unlike IAMS, RAMS provides the geospatial polygon location of certain assets which are linearly referenced and uniquely identified by an asset ID. Nevertheless, BIM or so called Highway Information Modelling (HIM) is gaining momentum in the design and construction phase of the Pan Borneo Highway project in Sarawak. These processes and the resulting models provide a significant source for capturing the geometric and geospatial location information that can be accommodated into current and future road asset systems.

4. Highway Information Modelling and Asset Tagging

The term Highway Information Modelling (HIM) has been an important in discussions within Sarawak and Federal PWD over the past two years. HIM reflects some of the digital engineering concepts and practices that are implemented through the application of both BIM GIS mapping and UAV technology in planning, designing and monitoring the construction of the on-going Pan Borneo Highway project. In this exercise, 2D CAD drawings are converted into construction 3D models and ultimately as-built models (shown in Figure 3). The 3D models provide simulation of construction objects (e.g. useful for clash detections) and also facilitate the extraction of quantities for construction of pavement, drainage, and sewage. Considering the lack of open data exchange standards for roads (e.g. Industry Foundation Classes or IFC), the 3D models are converted to i-Models to be used within ProjectWise and Navigator environments.

**Figure 3.** 3D Modelling using Autodesk + Bentley Microstation + Bentley i-Models
In the current discussion, the AssetWise network database and linear referencing engine is to be used to provide linear referencing capability to ProjectWise data (Figure 4). Asset or project location records can be stored and maintained in the AssetWise database in the form of network locations. Asset or project property attribute records and associated documents are stored and maintained in the ProjectWise database. The special features in AssetWise can be used to display the ProjectWise record on the AssetWise map. A link back to the ProjectWise database means that the map interface can be used to query attributes stored in ProjectWise.

An important requirement is to move design and construction data into the operation system. Design data will include alignments, asset inventory, bridge details, and drawings, 3D models and other data valuable to operations. The geometric alignment data is transferred by tracing function in the Linear Referencing System (LRS) tool. Asset inventory is also entered into the forms, or bulks loaded from files. Bridge detail and drawings, 3D models and other data valuable to operations can be accessed from ProjectWise. AssetWise supports data to be stored at the lane level as required to describe the lane, its construction history, condition, repairs from maintenance through rehabilitation/reconstruction and other affiliated data as identified by user. Data collected against the network using either linear referencing or sections can be retrieved against the chosen linear reference or section definition.

Asset tagging of HIM needs to be compatible with a framework of a federal Public Works Departments asset management system called MySPATA system (Government Asset Management System, in Malay). MySPATA is developed for registering necessary information about the federal government immovable assets including building and infrastructure assets (Figure 5 and 6). MySPATA system is supported by an asset tagging system called SKATA (Codes of Asset Tagging System, in Malay). Prior to this standard, there were various data collection methods used by agencies and there was no specific guideline in collecting assets location data. This caused the data collection being inaccurate, inconsistent and unsystematic.
Assets tags for physical road assets is divided into two codes 1) DPA which is the first level code structure and contains basic information about the owner and location of the asset 2) DKA which is the second level code structure and contains more detailed information about the road assets/components and their exact location. DPA tag is located at the start and final locations of each road and DKA tag is located at every 1 km. DKA represents the location of each asset and its components in terms of each road section number, subsection number, position (e.g. Left or Right), category and component code (shown in Figure 7).

Figure 6. MySPATA Application and Lifecycle Information Requirements

Figure 7. DPA and DKA Tags for Asset Types

5. Definition Categories and Sophistication Levels
The overview of road asset management systems and processes for Sarawak PWD road assets suggest that the linear referencing and GPS coordinates are the two main location referencing methods used for referring to the position of a location. On the other hand, the dimension of representation of assets vary
from zero-dimension (point locations) to 2D dimension (polygon representations) and 3D dimension objects produced from BIM models. In addition to GPS coordinates and linear referencing, geometric location definition is also found in the as-built BIM models. Table 3 shows various categories of location models which result from different location referencing types (providing positional and geometrical information) and level of dimensional details for locations representations.

Table 3: Location Definition for Road Asset Management System

| Road Asset Management Systems | Location Definition Categories | Level of Detail for Asset Representation |
|------------------------------|---------------------------------|------------------------------------------|
|                              | Geospatial Coordinates          | Zero Dimension Point – 1 – One-Dimension Polyline – 4 – Two-Dimension Polygon – 7 – Three-Dimension 3D object – 10 – |
|                              | Topological Linear Ref.         | – 2 – – 5 – – 8 – – 11 – |
|                              | Geometric Alignment             | – 3 – – 6 – – 9 – – 12 – |

It can be argued that current road asset management systems which are either fully adopted or considered, can be classified into three location definition sophistication categories depending on their level of dimensional details, and positional referencing (no geometric yet incorporated into the system). These categories include 1) Zero-dimensional linear referenced information 2) One dimensional geospatial polylines asset representation with zero-dimensional linear referenced information and finally 3) Two dimensional geospatial polygons asset representation with zero-dimensional linear referenced information. This means while some locations are captured and visualised using GPS coordinates, the information associated to assets are still tagged and located using zero-dimensional linear referencing.

Figure 8: Location Definition Sophistication Levels in Current PWD Asset Management Systems

In order to have an integrated asset management system which records various types of construction and maintenance data, it is not possible to rely on only one type of location referencing method and a specific level of dimension. Therefore, the integration of different location referencing methods and level of dimension is essential for creating an integrated asset management system. Higher level of sophistication means that systems can accommodate higher level of location dimension and also are potentially capable of capturing geospatial information. Having said that, none of the systems except BIM models are storing geometric data. The transfer of geometric information is currently done by tracing the geometric alignment and GPS tagging of road centreline and maybe other polyline/polygon assets.
6. Conclusions
The findings highlight that considering the increasing use of 3D geometric BIM models and geospatial information in individual asset management processes in Sarawak, more detailed and sophisticated location definitions models for current and future asset management systems should be considered. In particular, there is a need for incorporating higher level of dimensional details and higher variety of location referencing methods for collecting and recording information related to road assets lifecycle. Furthermore, it is essential to explore the ways to improve the automation for two-ways information exchange between the as-built HIM models and the geospatial systems. It is also recommended that future research explore the location definition of information that is captured by the automated data collection technologies and tools currently adopted in Sarawak road projects.

7. References
[1] Khan R, Liew M and Ghazali Z 2014 Malaysian Construction Sector and Malaysia Vision 2020: Developed Nation Status Procedia-Social and Behavioural Sciences 109 507-13
[2] Koen V 2012 Malaysia's Economic Success Story and Challenges Economics Department Working Papers (Paris: France Organisation for Economic Co-operation and Development)
[3] Kenley R, Harfield T and Behnam A 2016 BIM Interoperability Limitations: Australian and Malaysian Rail Projects MATEC Web of Conferences 001021-26
[4] Harun A 2016 Existing Practices of Building Information Modeling (BIM) Implementation in the Public Sector Supply Chain Manag. 5 166-77
[5] Latiffi A, Brahim J and Fathi M 2016 Transformation of Malaysian Construction Industry with Building Information Modelling (BIM) MATEC Web Conference 66 22-30
[6] Zainon N, Mohd-Rahim F and Salleh H 2016 The Rise of BIM in Malaysia and Its Impact towards Quantity Surveying Practice MATEC Web Conference 66 60-68
[7] Bradley A 2016 BIM for Infrastructure: An Overall Review and Constructor Perspective Automat constr. 71 139-52
[8] Kenley R and Harfield T 2016 Scoping Study for a Location Referencing Model to Support the BIM Environment AP-R568-18 (Sydney: Austroads Publication)
[9] Van der Velde J, Klatter L and Bakker J 2013 A Holistic Approach to Asset Management in the Netherlands. J Struct. Infrastruct. E. 9 340-48
[10] Bennett P 2013 Emerging Digital Mapping Requirements for C-ITS AP-R432-13 (Sydney: Austroads Publication)
[11] Sparrow M, Gallagher A and Patis M 2017 Digital Engineering for Bridge Infrastructure Projects Austroads Bridge Conference Melbourne, Australia
[12] Aram S and Eastman C 2013 Integration of PLM Solutions and BIM Systems for the AEC Industry Proceedings of 30th International Symposium of Automation and Robotics in Construction and Mining in Montreal 1046-55
[13] Shaw S 2013 Geographic information systems for transportation: from a static past to a dynamic future Ann. GIS. 16 (3) 129-40
[14] Hackeloer A 2014 Geo-referencing: A Review of Methods and Applications Ann. GIS. 20(1) 61-69
[15] Rehrl K 2017 Generation of Meaningful Location References for Referencing Traffic Information to Road Networks Using Qualitative Spatial Concepts Progress in Location-Based Services ed G Gartner and H Huang (Heidelberg: Springer) pp 173-91
[16] Saunders M, Lewis P and Thornhill A 2007 Research Methods for Business Students (Upper Saddle River: Financial Times/Prentice Hall)
[17] Hesse-Biber H and Leavy P 2010 Handbook of Emergent Methods (New York: Guildford Press)
[18] Sinha R and Hassan A 2014 Respondents versus Informants Method of Data Collection: Implications for Business Research MAJESS 2 1-13
[19] Transportation Research Board 2016 *Civil Integrated Management (CIM) for Departments of Transportation* ed W O’Brien (Washington DC: the National Academies Press)

[20] Vossebeld N and Hartmann T 2016 Modeling Information for Maintenance and Safety along the Lifecycle of Road Tunnels *J Comput. Civil Eng.* **30** 4-13

**Acknowledgments**

The authors would like to thank Swinburne University of Technology Melbourne Sarawak Research Collaboration Scheme ID number 3000004617 for providing funding for this research. Also, special thanks to Sarawak Public Works Department for facilitating the data collection process for this research. Last but