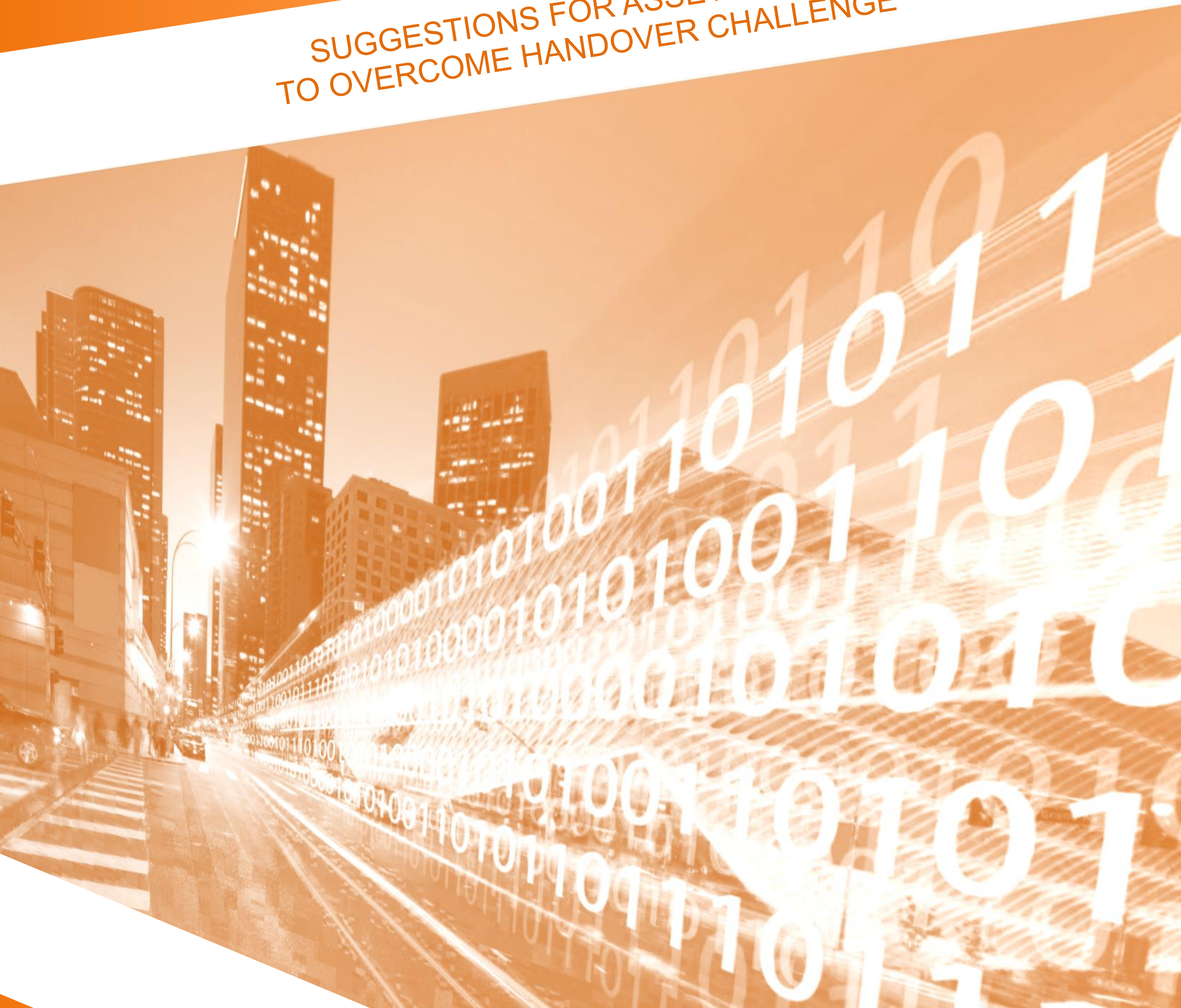
ASSET INFORMATION MANAGEMENT

SUGGESTIONS FOR ASSET OWNER TO OVERCOME HANDOVER CHALLENGE



MASTER OF SCIENCE THESIS

FAHAD RAHIMO

24 July 2018

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FOREWORD

Asset Management (AM) has been widely accepted by public road Asset Owners as a means to achieve a more efficient and effective approach to the management of roads through longer-term planning to ensure that performance requirements are defined and achievable within the available budget. Asset Information (AI) is required to support this approach to AM. AI describes the road assets an organisation has, where they are and how they perform. Moreover, AI enables effective and informed decision making in AM. Fundamental AI required for AM decision making is stored within the Asset Information Model (AIM). Within the AIM, the inventory module registers the assets an Asset Owner has and the corresponding locations. This module contains AI that is mostly static and describes the physical elements of the assets, such as the asset's name, location, length and width. This AI is often acquired during the AI handover, which takes place when the Service Provider has completed the construction of an asset on behalf of the Asset Owner and hands over the ownership of the asset, including the asset's AI, to the Asset Owner. However, previous research has demonstrated that many Asset Owners are challenged during the AI handover to acquire the AI they require for AM decision making [1]. Unfortunately, when Asset Owners want to retrieve AI to inform AM decision making they often discover too late that crucial AI is missing because it was not acquired during the AI handover [2]. This AI handover challenge has motivated the researcher, Fahad Rahimo, to dedicate this master thesis research to explore the challenge and determine how to overcome this challenge.

This document constitutes my thesis of the master's programme Civil Engineering & Management at the faculty of Engineering Technology of the University of Twente. Writing a thesis can be challenging without the proper knowledge, understanding and guidance. Therefore, this thesis would not have been possible without the time and support of many people. I am very grateful that dr. Andreas Hartmann and dr. Marc van Buiten, my supervisors from the University of Twente, have critically and encouragingly supported my academic development during this thesis writing. Moreover, I felt very honoured that Andreas Hartmann has appointed me as a research candidate to Arcadis, a global Design and Consultancy firm, and moreover, the project partner of this thesis. For this thesis, I was at the Arcadis office in Qatar for three months (October-December 2017), where I was warmly welcomed by the employees of Arcadis. Furthermore, I want to thank the employees of Arcadis Qatar for sharing their wonderful experiences of the Qatari construction industry. Not to mention, I also want to thank the employees of Arcadis in the Netherlands for sharing their advanced expertise regarding AM. The employees of Arcadis have inspired me to start my career within the AM field. Finally, I want to say thanks to all my dear family members and friends for their interest in my thesis and helping me enjoy my life outside this thesis project.

With the many valuable contributors to my master thesis, I am pleased to endorse this document and its recommendations. I encourage you to read the entire document. However, if your time is limited, it is important to understand the key points detailed in the summary on the next page. Please be aware that due to confidentially agreements, this public available document does not include

Fahad Rahimo

Author of this M.Sc. Thesis

SUMMARY

This research provides new insights into the challenge of Asset Information (AI) handover to the Asset Owner. Additionally, this research provides suggestions for the Asset Owner to overcome this challenge. AI handover occurs when the Service Provider has completed the construction of an asset on behalf of the Asset Owner and hands over the ownership of the asset, including the asset's AI, to the Asset Owner. The AI handover process involves the following activities – related to Asset Owner and Manager - : (1) specifying the Employer's Information Requirements (EIR) which is a contractual document that sets out all requirements concerning AI to be delivered by the Service Provider; (2) the moment when the Asset Owner acquires the handed-over AI from the Service Provider; and (3) the way the acquired AI is stored in the Asset Information Model (AIM) [3]. The AIM's purpose is to be the single source of approved and validated information related to assets. The AIM's aim is to provide AI to help Asset Management (AM) functions make better decisions [4]. Within the AIM, the inventory module registers which assets an organisation has and the corresponding locations. This module contains AI that is mostly static and describes the assets' physical elements, such as name, location, length and width. This AI is often acquired during the AI handover. However, previous research has demonstrated that many Asset Owners are challenged during the AI handover to acquire the AI they require for AM decision making [1]. Unfortunately, when Asset Owners want to retrieve AI to inform AM decision making they often discover too late that crucial AI is missing because it was not acquired during the AI handover [2].

In sum, the bottlenecks within EIR specification have a negative chain reaction on the follow-up AI handover activities – AI acquisition and AI storage. The bottlenecks within EIR specification might be seen as the primary bottlenecks that constrain the AI handover process in providing the AI used for AM decision making. To improve the AI handover process there must be an emphasis on the importance of specifying accurate EIR within contracts [8].

TABLE OF ABBREVIATIONS AND TERMS

ABBREVIATION	EXPLANATION
AI	Asset Information (detailed pieces of data and information about assets).
AIM	Asset Information Model
AIR	Asset Information Requirements
AM	Asset Management
ARCADIS	Global Design and Consultancy firm for natural and built assets and project partner of this research.
INVENTORY MODULE	A register of which assets an organisation has and where they are. This register contains Asset Information that are mostly static and describe the physical element of the assets.
ASSET MANAGER	Manages a portfolio of assets on behalf of the Asset Owner and translates the requirements to actions to achieve those requirements.
ASSET OWNER	Owns of a portfolio of assets and defines the asset's performance requirements, risks and budget.
BEP	BIM Execution Plan
BIM	Building Information Modelling.
CAD	Computer-aided design
EIR	Employer's Information Requirements
FHWA	Federal Highway Administration (United States Department of Transportation).
GIS	Geographic Information System
ISO	International Organisation for Standardisation
IT	Information Technology
LOS	Levels of Service
OIR	Organisational Information Requirements
PIM	Project Information Model
PMS	Pavement Management System
SERVICE PROVIDER	Provides its service to execute the actions that the Asset Manager has established.
UKRLG	United Kingdom Roads Liaison Group
UNIVERSITY OF TWENTE	One of the four technical universities of the Netherlands and supervising institute of this research.
VM	Value Management

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1. INTRODUCTION

Asset Management (AM) enables Asset Owners, through systematic and coordinated activities, to optimally manage its assets and their associated performance, risks and expenditures over their lifecycle to achieve its organisational plan [9]. For AM purposes, these Asset Owners typically invest heavily in an Asset Information Model (AIM). The AIM's purpose is to be the single source of approved and validated information related to assets. An AIM should provide better information to help AM functions make better decisions. Informed AM decision making is implemented through interpreting and analysing Asset Information (AI) stored in the AIM [4]. Therefore, the AIM should include AI that describes the assets, the spaces and associated items, asset performance and supporting information about the assets, such as specifications, operation and maintenance manuals, and health and safety information [10].

Several researchers have highlighted the importance of having an inventory of all types of assets as the first step of implementing an AIM [1, 11, 12, 13]. An inventory is a module within the AIM containing the AI describing the inventory of all assets owned by the Asset Owner. This module contains AI that is mostly static and describes the physical elements of the assets, such as name, location, length and width. Such AI enables the Asset Owners to understand which assets they have and the corresponding locations. Although the inventory module contains AI that is static, the asset network can change over time. The asset network can be physically changed due to major works on assets or newly built assets can be added. Therefore, AI resulting from major works on assets or newly built assets should be acquired in an accurate and timely manner [1, 13]. This AI is often acquired during the handover of these assets. The handover is the stage where the Service Provider has completed the construction of an asset on behalf of the Asset Owner and hands over ownership of the asset, including AI, to the Asset Owner. However, previous research has demonstrated that many Asset Owners are challenged during the AI handover to acquire the AI they require for AM decision making [1]. Unfortunately, when Asset Owners want to retrieve AI to inform AM decision making they often discover too late that crucial AI is missing because it was not acquired during the AI handover [2].

1.1. RESEARCH QUESTION

The main research question arises from the research problem and objective and is defined as follows:

> *"What are the bottlenecks that constrain the Asset Information handover process in providing the Asset Information for Asset Management decision making? "*

1.2. RESEARCH DESIGN

When doing an thesis project at an external organisation (such as a company or institute) some formalities need to be signed in an agreement. Note that the University of Twente is a public institution funded by the government, therefore the aim is to publish all information resulting from a student project. From the above it might be obvious that it is important to produce a report that can be published. Therefore make sure that that no confidential information is included in the final report. Based on the latter, this report provides does not provides the results of this thesis project and other confidential information has been excluded in this report.

The literature review provides a theoretical research framework, which represents the AI used for AM decision making and how the AI handover process should provide this AI. The following parts are not included in this documented, but are discussed anyways in this research design. Based on the theoretical research framework, interview questions were formulated to contextualise the framework within the context of the external organisation. The interview questions were semi-structured, which enabled the interviewees to add new insights. A structured interview approach was not used because answers are confined [19]. The results contextualise the research framework within the context of the external organisation to identify the bottlenecks that constrain the AI handover process in providing the AI used for AM decision making. This aim is achieved through interviews with the employees of the external organisation and reviewing organisational documents. The recommendations provide suggestions for the external organisations to mitigate the identified AI handover process bottlenecks.

2. LITERATURE REVIEW

This chapter describes the findings from a literature review on Asset Management (AM) (roles, processes and decision making, Asset Information (AI) used for decision making) and the AI handover process (Employer's Information Requirements (EIR) specification, AI acquisition and AI storage). Section **2.1** provides insight into the decision making within AM and the AI used for this decision making. Furthermore, as mentioned in the research scope, this research focuses only on the decision making within the AM process of identifying and prioritising project schemes. Then, section **2.2** describes how the AI handover process should provide the AI used for this AM decision making. Finally, in section **2.3**, the theoretical research framework presents the AI used for AM decision making and details how the AI handover process should provide this AI.

2.1. ASSET MANAGEMENT

The ISO 55000 standard includes a well-considered definition for AM as "the coordinated activity of an organisation to realise value from assets", and where an asset is an "item, thing or entity that has potential or actual value to an organisation" [20]. Value from assets is realised through balancing costs, risks, opportunities and performance benefits over the life cycle of an asset [21]. The AM's purpose is to support the delivery of organisational objectives and maximise the value generated by the assets. AM involves a trade-off between the assets' performance, expenditure involved in the processes, and the risks faced by the business considering the operations, environment and constraints.

Figure 1 provides a representation of factors that contribute to the value of assets to an organisation. The outer 'wiring' refers to the main interactions and management and trade-offs between these dimensions. The primary objective of AM is ensuring that these trade-offs are correct. As illustrated in Figure 1, there are many elements that can contribute to assessing the value of an investment to an organisation [22].

Figure 1: Dimensions of Asset Value [17]

Coordinating the many facets of AM requires a system of direction and control. The ISO 55000 standards describe a management system for AM. An Asset Management System is used by an organisation to direct, coordinate and control AM activities. An AM system enables an organisation to establish an AM policy, objectives and processes to achieve those objectives. An AM system can provide improved risk control and assurances that AM objectives are consistently achieved. However, not all AM aspects can be formalised through an AM system. For example, aspects such as leadership, culture, motivation and behaviour, which can significantly influence the achievement of AM objectives, may be managed by an organisation using arrangements outside the AM system. ISO 55000 states that when the AM System is aligned with an organisation's over-arching corporate management system, the results can be highly effective. This alignment is known as the 'Line of Sight', which connects the organisation's strategic objectives with the AM activities delivered by staff [21].

2.1.1. ROLES

Within AM, three roles can be distinguished, namely [11];

- **The Asset Owner**: Operates at a strategic level and initially implements the AM system. The implementation of an AM system includes the development of an AM policy, objectives and processes to achieve those objectives [21]. AM objectives are related to stakeholder expectations of from the assets. Therefore, the Asset Owner should identify and manage stakeholder requirements regarding the assets. Based on these requirements, the Asset Owner determines the Levels of Service (LOS) - the objectives the organisation wants to achieve. The LOS must be guaranteed to satisfy the stakeholders. As such, LOS are the agreed level of performance that must be met and are recorded in a service level agreement between the Asset Owner and Asset Manager [23];
- **The Asset Manager**: Operates at a tactical level and develops an implementation plan for the AM system. An implementation plan, in practice, often describes how the Asset Owner could achieve accreditation against the ISO 55000 [24]. Following the AM system, the Asset Manager determines what must be implemented where and when to realise the objectives set within the LOS. Through a works programme, the Asset Manager specifies the activities an organisation must undertake to deliver the agreed service levels [21];
- **The Service Provider**: Implements the works programme developed by the Asset Manager [21]. The Service Providers must ensure that work programmes can be implemented within the agreed budget and timescale. Furthermore, the Service Provider reports on the performance of the assets via frequent inspections [24].

Figure 2: Asset Management roles [7]

2.1.2. PROCESSES

Although AM has been the subject of practice and research for decades, there is no common understanding of AM [25]. Typically, AM is addressed by systems meant to guide users through sequential processes and making rational choices. The Institute of Asset Management states that there is no perfect system to describe the AM processes and it may be necessary to modify elements of a selected AM system to better meet the Asset Owner's needs [21]. This research addresses the AM system developed by the UK Roads Liaison Group and implemented by Highways England, which is presented here in three parts: context, AM planning and AM enablers [24]. The context describes the environment within which the service is delivered, AM enablers defines the enablers that support implementation of the AM system, such as organisational characteristics, risk management and AIM or in regard to the UK Liaison Group, Asset Management Systems [24].

AM planning describes the key activities and processes for AM planning and provides advice on how these should be applied to assets. The AM planning process starts with defining the AM policy and strategy. The AM strategy describes how the Asset Owner should deliver AM to meet its strategic objectives. As part of the AM strategy, the Asset Owner should develop the LOS, which describes the desired asset performance, such as safety, serviceability and sustainability. Subsequently, performance measures are developed to monitor whether the LOS are met. Within lifecycle planning, the Asset Manager determines what must be implemented where and when to achieve the LOS. Lifecycle planning comprises the approach to maintaining an asset from construction to disposal. This process involves predicting future performance of an asset or group of assets based on investment scenarios and maintenance strategies. Maintenance strategies that consider the different treatment options and balance renewal with routine maintenance may be developed. These strategies should consider the service life of each treatment option and balance the costs over a planned period. The objective of developing maintenance strategies is to provide a lifecycle plan for an asset that supports the AM strategy. To develop lifecycle plans, AI should be available within the AIM in terms of the inventory, performance, routine maintenance and treatment options.

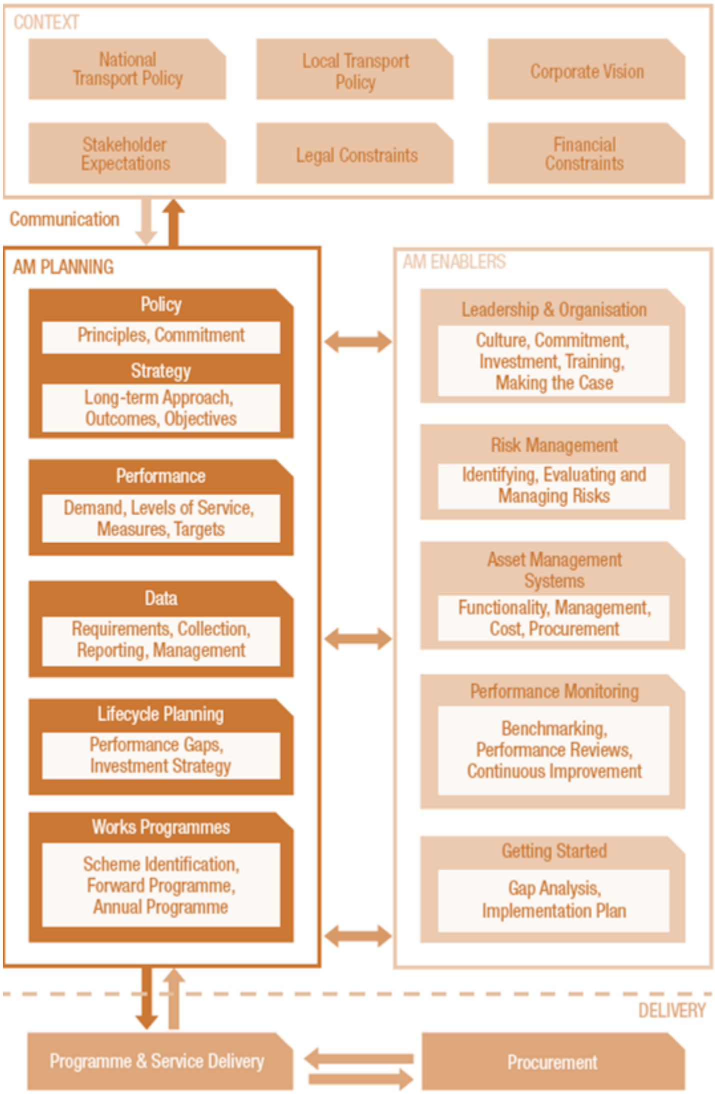

Figure 3: Asset Management processes [19]

The tangible outcome of the AM planning process is the delivery of a works programme. A works programme's purpose is to produce the highest priority maintenance project schemes from the available annual budget. The process of developing a works programme for asset maintenance comprises the identification, prioritisation, optimisation, programming and delivery of individual project schemes [24]. Before project schemes can be prioritised, priced options for maintenance should be developed for each scheme. Ideally, selected treatment options should align with those developed for lifecycle plans.

The process of identifying and prioritising project schemes

As mentioned, the development of a works programme for asset maintenance comprises the identification, prioritisation, optimisation, programming and delivery of individual project schemes. As discussed in the research scope, this research focuses on the process of identifying and prioritising project schemes (Figure 4).

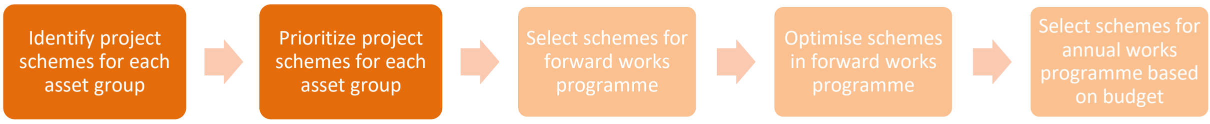

Figure 4: Developing a Works Programme

Identifying project schemes is where the organisation identifies which maintenance works are required to manage asset failures that are reasonably likely to affect that asset [26]. These project schemes may be collated into an annual works programme. However, it is likely that there is an insufficient budget to manage all these project schemes. If this is the case, it is probable that those schemes considered safety critical or with a high level of risk carry the highest priority. Therefore, project schemes are prioritised to identify which of those schemes require the most immediate action and create a list of future schemes sufficiently in advance to ensure effective planning and preparation. There are several techniques available to prioritise competing project schemes. Some of these techniques supporting the decision making of prioritisation are discussed in the next section.

Once the priority of each project scheme is determined, the schemes to be collated in a works programme can be selected based on their priority number. Initially, all selected project schemes are categorised into the forward works programme, which comprises the project schemes to be carried out within the following three to five years. In some cases, where the AI is available, indicative forward programmes can be developed for longer periods. Subsequently, the project schemes in the forward programme can be optimised based on selected criteria, which may include the following considerations:

- **Minimise occupation of the network**: Value of these schemes are maximised through coordination with other works programmes and integrated projects on related parts of the network, thus minimising disruption to users and maximising benefits to the community;
- **Deliver efficiencies by combining activities**: Several schemes may be combined and delivered together, for example, schemes carried out in close geographical proximity but scheduled in different years.

Finally, the annual works programme is developed from the forward programme and includes, effectively, the highest priority project schemes that can be delivered from the available annual budget. Ideally, project schemes in the annual works programme should be designed and ready to be delivered. This preparation enables the Service Providers to plan the project schemes properly and minimise any potential risks associated with the delivery. Furthermore, the remaining project schemes within the forward works programme should be regularly updated and inclusion of newly identified project schemes may be required.

2.1.3. DECISION MAKING

AM processes are not always clearly identifiable in AM systems, and the number and type of decisions differ between systems [25]. However, AM has a hierarchy of decision-making levels. The decision levels pertaining to AM can be divided into strategic, network and project levels [27, 28, 29]:

I. **Strategic decision-making level**: refers to strategic resource allocation and utilisation decisions concerning all types of assets;
II. **Network decision-making level**: refers to determining the overall maintenance, rehabilitation, construction strategies and work programs. The network level is itself often further divided into program and project selection levels:
    i. **Program decision-making level**: concerned with decisions about the network-wide programming of actions and allocations. This level is involved in policy decisions, and the aim is system-wide optimisation of funds allocated to rehabilitation, maintenance or new construction of assets;
    ii. **Project selection decision-making level**: concerned with decisions about funding for projects or groups of projects and provides a link between the network level and the subsequent project level;
III. **Project decision-making level**: concerned with decisions about the design of projects included in the overall work plan required to meet the agency's performance measures.

Decision making of identifying and prioritising project schemes

The decision making of identifying and prioritising project schemes pertains to the network decision-making level and, in particular, the project selection decision-making level. Project selection follows the policies of the overall network programming decision level regarding the funds to be allocated in different works programmes [30]. After an organisation has defined the amount of available funds for each work programme, the project that fits into each of these works programmes must be determined. Before deciding which projects fit into each works programme, organisations should understand which projects should be executed to achieve the LOS [29].

Project scheme identification implies the analysis of a given asset to determine what treatment options, if any, should be taken to maintain or improve its performance [31]. The identification of project schemes involves identifying the physical length of the asset requiring maintenance, including treatment options and costs [32]. Typically, the following range of treatments options should be considered [24]:

- **Do nothing**: Under a 'Do nothing' treatment option, reactive repairs are made only to safety failures. These repairs are likely to be superficial and possibly temporary. The repairs do not arrest the decline of the asset's performance and frequent re-visits are likely. In the context of a pavement project scheme, this option could mean the treatment of a collapsed road or comparable severe surface defects, which have led road users to lose control of their vehicles;
- **Do minimum**: This approach seeks to perform the minimal amount of routine maintenance work to keep the asset safe and serviceable. Works are normally restricted to the repair of asset failures. However, the works effort are slightly enhanced compared to 'Do nothing' as repairs are normally permanent – although they add no value to the asset. In the context of a pavement project scheme, a 'Do minimum' approach might only be limited to the permanent repair of potholes.
- **Do something**: This option is likely to involve capital expenditure by an Asset Owner rather than routine expenditure. 'Do something' may include wholesale replacement or major repair of an asset to a level that enhances its long-term durability and minimises future routine maintenance. A pro-active approach may also be adopted, meaning that repair occurs before the condition intervention level is reached. In the context of a pavement project scheme, this option could see the treatment of a section of pavement classified as being in the 'Amber' condition category (in a traffic light system of red, amber and green).

After the treatment options are evaluated for each project scheme, the competing project schemes should be prioritised. Different decision-making techniques may be useful for prioritising project schemes, namely:

- **Lowest whole life cost**: is a cost-benefit analysis that quantifies the investment costs, including the costs of treatment and subsequent maintenance interventions, against economic benefits, including safety, traffic delays and pollution. These should be assessed for each treatment option. The treatment option with the lowest Net Present Value (NPV) over the period of analysis provides the lowest whole life cost. This technique may be useful for prioritising project schemes for carriageways, structures or lighting;
- **A risk-based approach**: may be more appropriate for assets such as drainage, earthworks, safety fencing and assets on remote parts of the network. This approach identifies the impact on local communities, in terms of safety and serviceability of not undertaking the work, by calculating a risk rating. Asset with the highest risk rating is assigned the highest priorities;
- **Value Management:** is a multi-criteria decision-making process that can be used to prioritise project schemes. Ideally, the criteria adopted should align with the approach to asset management, particularly the levels of service. This prioritisation process requires each criterion to be assigned a weighting, which represents its importance in the delivery of the asset management approach. While it is recognised that safety is of primary importance, other issues should also be addressed, including serviceability, sustainability, stakeholder requirements and value for money.

In sum, decision making within the process of identifying and prioritising project schemes depends on the decision-making techniques used. Therefore, no justified statement can be made about exact decision making within this process.

2.1.4. ASSET INFORMATION USED FOR DECISION MAKING

Asset Owners must understand which AI is used for AM decision making, which in turn, drives an action. If AI is handed over to the Asset Owner and not used, then it is worth asking what value is gained from collecting it. Understanding the use of AI may also raise questions about which AI is turned into the desired knowledge and how this knowledge influences a decision, including what an accepted time lapse is between AI being collected and then used to inform a decision [4]. The answers to these types of questions lead to the AI Requirements (AIR) specification, which is elaborated on in the next section.

In general, there are several typically used AI used within decision making of the AM process for identifying and prioritising project schemes. AI is crucial for this decision making and can be used to define the physical characterises of the asset under consideration. Table 1 provides an example of the AI that is stored within the inventory module. This AI can be used in this decision making [33]. Besides the AI stored within the inventory module, other types of AI can be used, which can be obtained from the following AI sources [24]:

Table 1: Example of the AI stored within the inventory module

	ASSET GROUP	ROADWAY
ASSET REGISTER	Asset Type	Regional Roads
	Asset	Road Name and Number
	Component	Road Segment
	Sub-component	XSP (Cross-sectional position) /Lane
INVENTORY AI	Inventory	Length, Width, Traffic Impact Number, Surface type, Surface material specification, Material source, Date of last resurfacing, environment, construction type, Surface treatment type, Date of last surface treatment.

- Results from inspections and condition surveys;
- Surveys where the primary objective is not to assess an asset's condition, such as safety inspections. This source may provide information about the assets' performances and risks;
- Local knowledge from operational staff involved in managing the network, including inspectors and Service Providers;
- Stakeholder needs, particularly aspects important to the local community;
- Complaints and areas where there is a large number of personal injury accident claims;
- The requirements for meeting wider transport and corporate objectives.

The way in which the identified project schemes are prioritised involves decision-making techniques similar to those described in section **2.1.3**. Therefore, it is reasonable to assume that the AI used at this level of decision making should include the type of AI that forms the input of these techniques. In other words, project scheme prioritisation AI needs should focus on the inputs the techniques require. As different Asset Owners employ different decision-making techniques, the AI used by each Asset Owner is also expected to be different [28].

In sum, Figure 5 and Figure 6 illustrate the possible AI inputs and outputs within decision making in the process of identifying and prioritising project schemes.

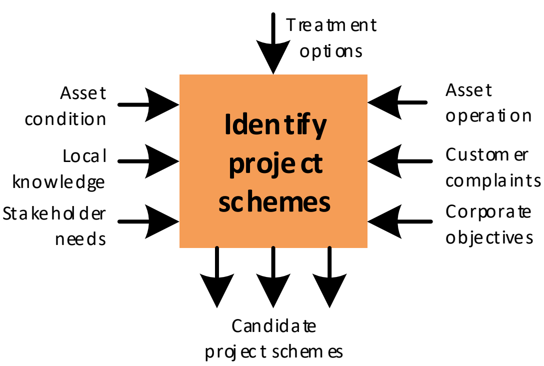

Figure 5: Asset Information used to identify project schemes [63]

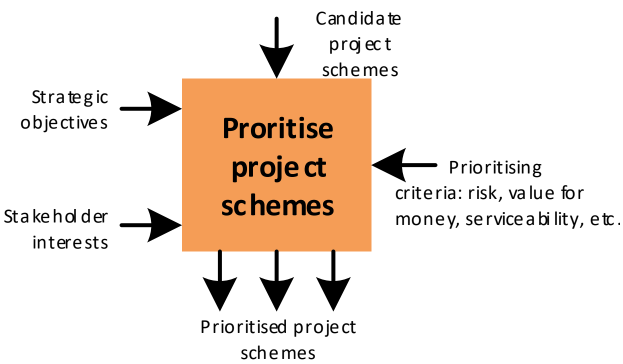

Figure 6: Asset Information used to prioritise project schemes [63]

2.2. ASSET INFORMATION HANDOVER PROCESS

The British Standards Institution (BSI) developed the PAS 1192-2 as an immediate response to the industry need to solve the AI handover challenge. The PAS 1192-2 provides a framework for information management for the asset delivery phase of construction projects [3]. This framework also aligns the different project stages and recognises that AI is increased throughout the asset delivery phase of construction projects. At the final point of the asset delivery phase the new asset is handed over to the Asset Owner. At this point, with the AI at its richest, AI is passed to the Asset Owner to enable the Asset Owner to maintain and operate the new asset [3].

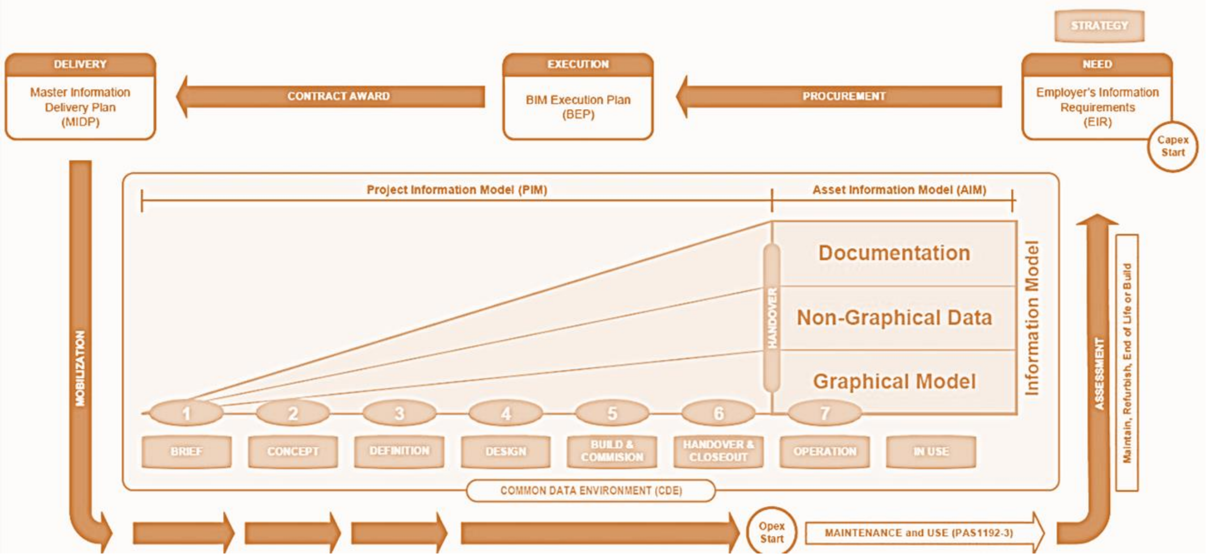

Figure 7: Information delivery cycle [3]

The AI handover process starts with the Asset Owner's state of need, as depicted in the upper right corner of Figure 7. Within this state of need, the Asset Owner outlines the Employer's Information Requirements (EIR). The EIR is a contractual document that sets out all requirements concerning AI to be delivered by the Service Provider. As such, the EIR identifies the downstream uses of AI during the operation and maintenance at the outset of the design and construction phase of a project. In other words, commencing with the end in mind. The EIR forms part of the project contract and enables the Service Provider to produce their initial BIM Execution Plan (BEP). The BEP sets out which AI should be generated, who must prepare it and the protocols and procedures for its production and release. AI generated in the project delivery process sits within the Project Information Model (PIM). The PIM is an information model developed by the Service Provider during the design and construction phase of a project. Furthermore, the BEP supports the project team to mobilise and commence the asset delivery phase and build their PIM in full alignment with the EIR. At the final point of the asset delivery phase, the new asset and the PIM is handed over to the Asset Owner. At this point, the Asset Owner acquires the AI stored in the PIM [3]. The Asset Owner is interested in AI representing what has actually been constructed and not what the designers intended. Therefore, the Service Provider delivering the PIM should ensure that the PIM includes AI describing the As-built asset situation [10]. Once the Asset Owner verifies the acquired AI, the AI stored in the PIM must be uploaded to the Asset Information Model (AIM). The AIM's purpose is to be the single source of approved and validated information related to assets. The AIM includes AI describing the asset(s) and its associated space(s) and item(s), information about performance of the asset(s), supporting information about the asset(s), such as specifications, operation and maintenance manuals, and health and safety information. The AIM can be continually enriched during the maintenance and operational phase [3].

Based on the information delivery cycle defined in the PAS 1192-2, it can be argued that the AI handover process involves the following activities: (1) specifying the EIR; (2) the generation of AI throughout the asset delivery phase of construction projects; (3) the moment the Asset Owner acquires the handed-over AI from the Service Provider and; (4) the way the acquired AI is stored in the AIM [3]. Figure 8 provides a visualisation of the AI handover process. The red items indicate the AI handover activities related to the Asset Owner and Manager, whereas the blue items indicate the activities related to the Service Provider.

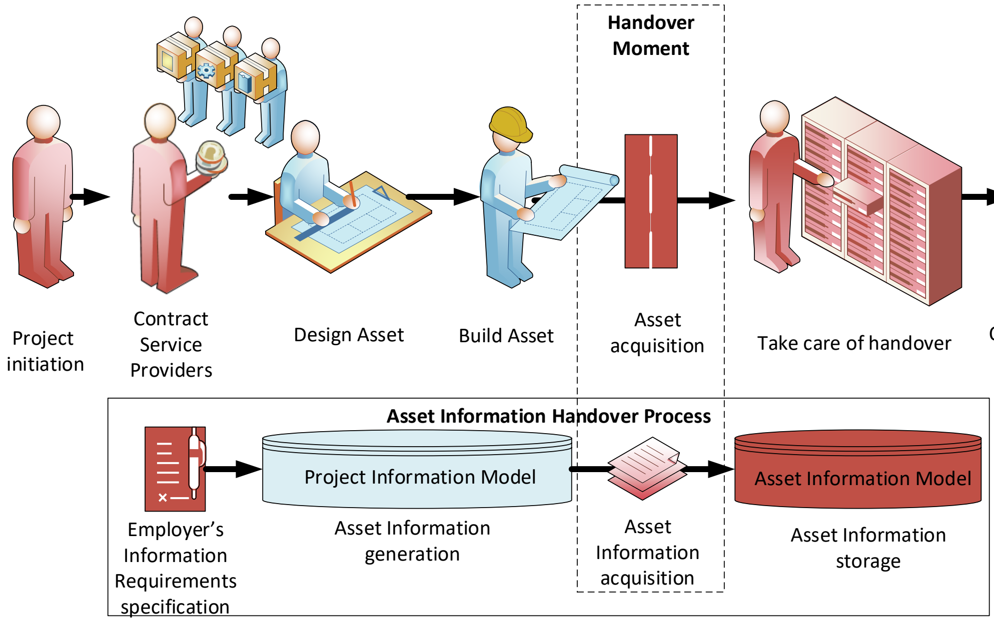

Figure 8: the Asset Information handover process

In sum, this research is interested in the AI handover activities related to the Asset Owner and Manager. As such, this research focuses only on the AI handover activities related to the Asset Owner and Manager, and not those related to the Service Provider. Based on Figure 8, it can be argued that the AI handover process involves the following activities – related to the Asset Owner and Manager - : (1) EIR specification; (2) AI acquisition; and (3) AI storage [3].

2.2.1. EMPLOYER'S INFORMATION REQUIREMENTS

The EIR sets out all requirements concerning AI to be delivered by the Service Provider. The process of specifying the EIR is defined within the PAS 1192-3 (2014). The PAS 1192-3 adopts a top-down approach to specify EIR from an organisational level down to the asset- and project-specific level (Figure 9).

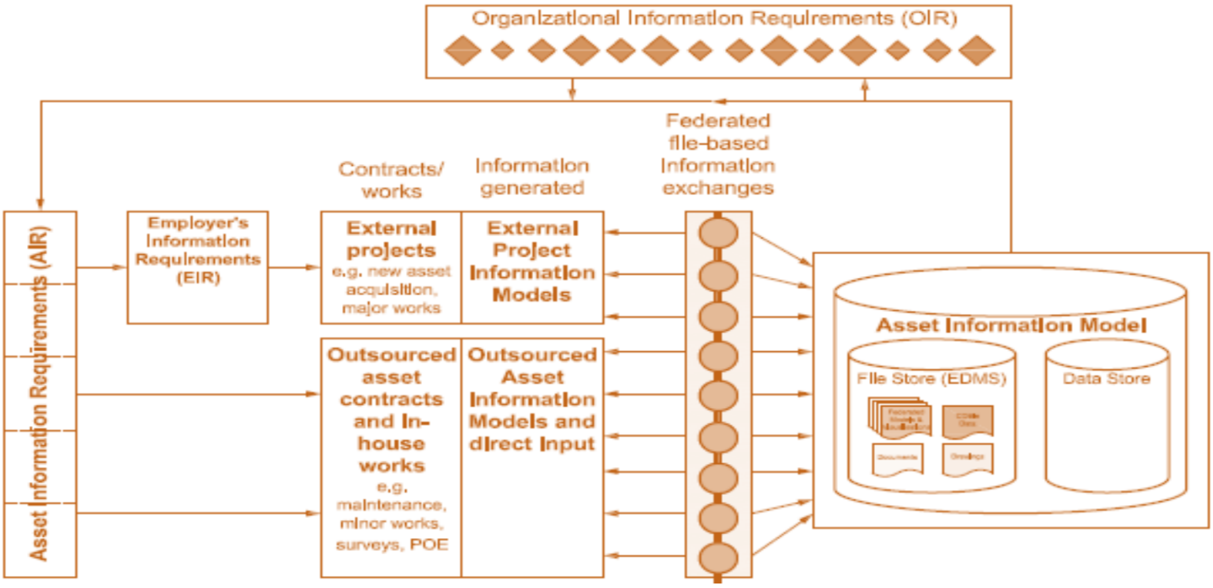

Figure 9: Specifying Asset Information Requirements [10]

The Organisational Information Requirements (OIR) are the information an organisation must know about its assets to inform AM decision making. A typical decision that drives an OIR might be addressing the question of which assets need maintenance. Such a decision might be informed by a single piece of AI, but usually requires an aggregation of several pieces of AI. Therefore, the AIR sets out what AI is required to inform each OIR. Referring to the example question of which asset need maintenance, the organisation must collect AI that can result from inspections, conditions surveys, customer complaints and accident claims to inform this decision. The AIR requires the organisation to classify the AI entered into the AIM according to an agreed classification system [10]. Furthermore, AI can be collected from maintenance, minor works, surveys, major works and building new assets. In the cases of maintenance, minor works and surveys, an existing asset may be modified. Therefore, the AI for that asset must be updated. In this case, in-house teams or Service Providers can directly access the AIM and update the existing asset's AI. However, in cases of major works on assets and newly built assets, a new asset, which is not yet registered in the AIM, is created. The AI related to this new asset is often stored in the PIM. Therefore, additional requirements are required to enable the transfer of AI from the PIM to the AIM [10]. These requirements are captured in the EIR. Note, it is called Employer's Information Requirements rather than 'Asset Owner's' or 'Clients' Information Requirements as the document is meant to be used throughout the asset delivery phase of construction projects, so anybody required to submit AI to another party on the project must adhere to the EIR. The EIR should cover the following three areas [34]:

- **Technical information**: the AI's level of detail to be supplied. Software platforms used should be detailed, including the AI formats required;
- **Management information**: the processes and procedures to be adopted to manage AI flow in the project;
- **Commercial information**: AI deliverables, models required, the timing of AI delivery and how the AI is to be used.

Finally, The EIR forms part of the project contract and enables the Service Provider to produce their initial BEP. The BEP lists AI deliverables and sets out when the project is to be prepared, by who and using what standards and procedures for each project stage [10].

2.2.2. ASSET INFORMATION ACQUISTION

Based on the EIR specified in the contract, the Service Provider generates and delivers the required set of AI to the Asset Owner. However, previous research has demonstrated that many Asset Owners are challenged during the AI handover to acquire the AI they require for AM decision making [1]. Unfortunately, when Asset Owners want to retrieve AI to inform AM decision making they often discover too late that crucial AI is missing because it was not acquired during the AI handover [2]. AI accuracy and relevance are the most critical variables in terms of AI management and for a smooth AI handover, it is imperative that the Asset Owner proactively specifies the EIR at the start of the life cycle [8]. In addition, AI in the PIM are often stored in other systems that use different formats and structures than used in the AIM [35, 36, 37]. Therefore, this AI must be converted to the required formats and structured before it can be uploaded to the AIM. As the result, the handed-over AI must be manually entered into the AIM [35]. The Asset Owner's misconception of the importance of the AI format is one of the reasons attributing to the AI handover challenge [38]. This misconception suggests that Asset Owners are too focused on the AI and not enough on the medium used [38]. Table 2 highlights the bottlenecks attributing to the AI handover challenge.

Table 2: Summary of some issues related to Asset Information acquisition

CATEGORY	***ISSUE***
Asset Owner	*Asset Owners often have unclear standards for AI handover and, therefore, the clarity and completeness of handed-over AI is affected* [8].
	Asset Owners often have unclear roles and responsibilities for capturing AI from the Project Information Model and transferring this AI to their Asset Information Model [39].
	Asset Owners often do not have effective processes in place to control and verify the handed-over AI and their quality [37, 40].
Service provider	*Service providers often do not have prior experience on how to deliver As-built AI that supports the Asset Owner's AM activities* [8].
	Service providers wait to the end of construction to hand over AI, which results in hurried and, therefore, inaccurate delivery of AI and inefficiencies and delays in being able to use the AI [41, 42].
Technical	*Challenges to update As-built AI from small projects, work orders and major renovations within the Asset Information Model* [43].
	Interoperability between the Project Information Model and Asset Information Model leads to difficulties in transferring the AI between the two models [36, 37, 40].

In sum, Asset Owners seek scalable approaches to AI continuity as they commission projects and take over built assets. It can be noted that capturing AI from projects is important [36]. However, acquired AI is often untimely, project documentation is not structured, complete, reusable and often contains inconsistencies [35, 2].

2.2.3. ASSET INFORMATION STORAGE

During the AI handover, Asset Owners acquire bulk AI, for example, As-built drawings, warranty documents, commissioning reports, and maintenance and operation manuals [2]. These different types of AI must be manually sorted to store each type of AI to its associated information system. These information systems can be a Pavement Management System (PMS), Geographic Information System (GIS) or Enterprise Resource Planning (ERP). The AIM's purpose is to integrate all information systems into the model so all different types of AI can be centralised. Thus, the ultimate goal of integrating these information systems to the AIM, as illustrated in Figure 10, is to create an information-enabled integrated view of AM so organisations have complete AI about an available asset. In theory, the AIM's major role is to collect and store AI and provide decision support capabilities via analysing this AI [44]. However, information systems not integrated with the AIM are common within AM organisations. In these cases, AI is stored in isolated information systems and, therefore, the AM objective of an information-enabled integrated view of AM is constrained [44].

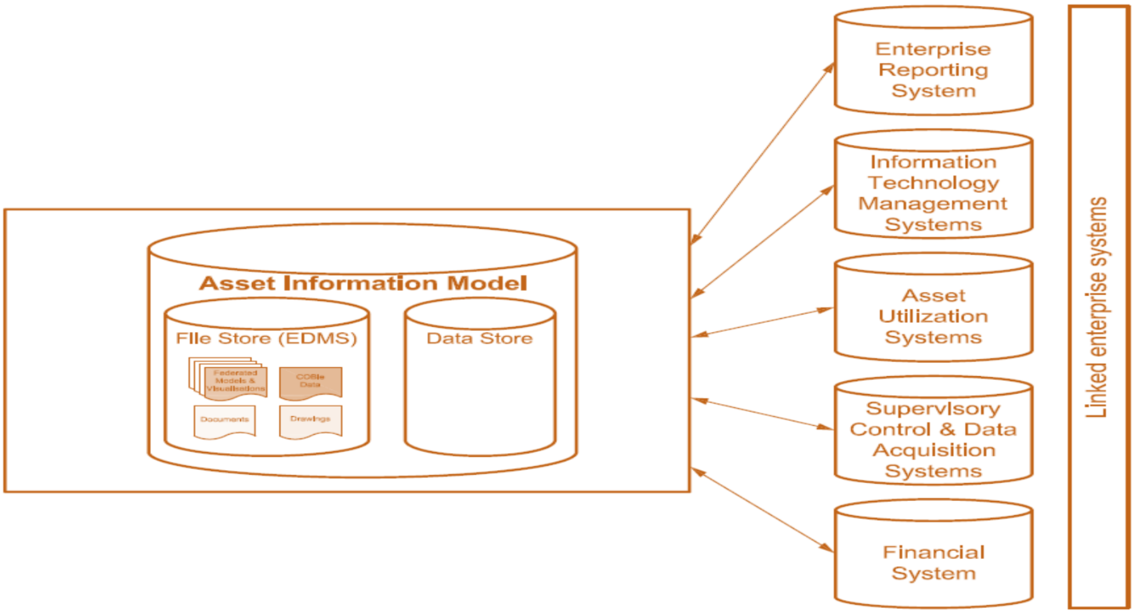

Figure 10: Interface between AIM and integrated information systems [10]

The AIM can contain multiple modules. For instance, the following modules are known in IBM Maximo (an AIM): Assets, Contracts, Deployed Assets, Inventory, Planning, Preventative Maintenance, Purchasing, Resources, Safety, Self-Service, Service Desk Service Management and Work Orders. The AI stored within information systems is (automatically), if integrated with the AIM, passed to the associated AIM's module [45]. For example, AI resulting from As-built drawings are often stored within GIS and this AI is passed to the inventory module.

In sum, the promising theoretic value from AIM, such as the creation of an information-enabled integrated view of AM, depends on a variety of technical, organisational and social factors. According to Haidar (2012), barriers to successful utilisation can be traced to two bottlenecks, i.e., inadequate organisational planning and preparation for AIM implementation and disregard of organisational and social changes associated with AIM implementation. Therefore, AIM use requires a certain level of organisational, cultural, procedural and structural maturity to produce the desired output [44].

2.3. THEORITICAL RESEARCH FRAMEWORK

This section presents the theoretical research framework, namely the AI used for Asset Management AM decision making and how the AI handover process should provide this AI (Figure 11). In essence, this research framework links the topics presented in the literature review and discussed in sections **2.1** and **2.2**. As mentioned in the research scope, this research focuses on the AM process for identifying and prioritising project schemes and, therefore, AI for decision making within this process. The AI used for AM decision making is linked to the AI handover process because this AI may be provided during the AI handover process, which involves the following activities – related to Asset Owner and Manager - : (1) specifying the Employer's Information Requirements (EIR) which is a contractual document that sets out all requirements concerning AI to be delivered by the Service Provider; (2) the moment when the Asset Owner acquires the handed-over AI from the Service Provider; and (3) the way the acquired AI is stored in the Asset Information Model (AIM) [3].

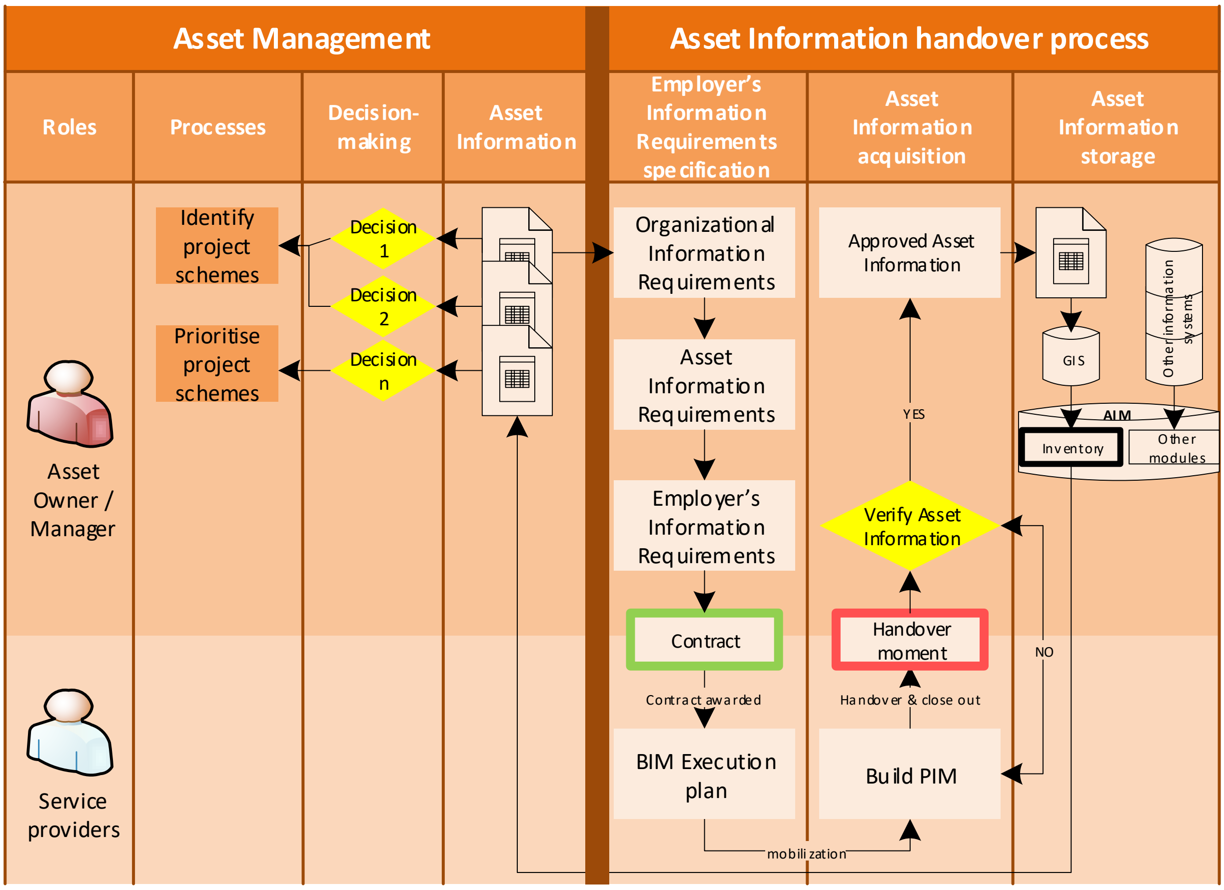

Figure 11: Theoretical research framework

3. DISCUSSION

The first point of discussion, the specification of EIR can be a challenging task because specifying EIR can also be limited due to social and organisational factors. The most well-known reasons for incorrect and incomplete EIR are the challenges in description, communication issues between users and analysts, lack of user involvement in EIR elicitation and changing EIR [54]. Therefore, having a contract with complete EIR should not be the only focus of the organisation to improve EIR specification. Organisations must also emphasise their social and organisational capabilities when specifying EIR.

The second point of discussion concerns the final output of specifying EIR. Based on the EIR, the Service Provider develops a BIM execution plan (BEP) - the primary plan for the preparation of project information and adoption of the BIM standards required by the EIR. Specifying clear EIR is a well-known challenge in the Qatari construction industry [53]. There are significant challenges related to the lack of Qatari-specific BIM standards, BIM dictionary, project work activities and capability assessment. Due to the lack of a Qatari construction industry BIM standard, Asset Owners leave the selection of a BIM standard to the Service Provider. This approach challenges Service Providers because most of these providers in Qatar do not have sufficiently skilled employees required for this task [53]. The challenges in BIM adoption puts pressure on project teams to coordinate the creation and collection of AI in a BIM model and eventual handover a complete and accurate PIM to the Asset Owner [55].

The third point of discussion concerns AI storage within the Asset Information Model (AIM). The AI stored in the PIM should be transferred to the organisation's information systems. All information systems should be integrated to the AIM, which centralises all AI and is used to extract AI to inform AM decisions. It is only under these conditions that organisations can extract the required AI to inform AM decisions. However, it is common in AM organisations that information systems are not integrated with the AIM. As a result, AI is stored in isolated information systems and consequently, the AM objective of an information-enabled integrated view of AM is constrained [44]. The primary reason for isolated information systems lack strategic views on information systems. Traditionally, Asset Managers have focused on developing the technical foundation for AM and left the selection, adoption and maintenance of information systems to IT (Information Technology) managers. IT managers mainly focus on implementing information systems which may serve the needs of individual departments but do not contribute to an integrated, information-enabled view of AM. Moreover, this issue is attributed to the propensity of Asset Managers to view information systems utilisation in general as a secondary activity to executing business process. As a result, the existing information systems, in general, are not aligned with the strategic AM considerations, do not contribute to functional integration and do not conform to AIM principles [44].

The fourth point of discussion concerns the limitations of this research, which may have impacted interpretation of the findings. Furthermore, to understand all AI handover activities, including the activies related to the Service Provider, the researcher should have interviewed the Service Providers. However, these interviews were not conducted as the Service Providers were not available for an interview. Further limitations were the lack of research papers about the AI used for the AM decision making within the process of identifying and prioritising project schemes. This process is of vital importance to the overall success of AM as it links AM strategy with specific projects [29]. Therefore, this research aims to motivate further research directions to address the research gaps of AIR for identifying and prioritising maintenance projects.

4. CONCLUSION

This research provides new insights into the challenge of Asset Information (AI) handover to the Asset Owner. Additionally, this research provides suggestions for the Asset Owner to overcome this challenge. AI handover occurs when the Service Provider has completed the construction of an asset on behalf of the Asset Owner and hands over the ownership of the asset, including the asset's AI, to the Asset Owner. The AI handover process involves the following activities – related to Asset Owner and Manager - : (1) specifying the Employer's Information Requirements (EIR) which is a contractual document that sets out all requirements concerning AI to be delivered by the Service Provider; (2) the moment when the Asset Owner acquires the handed-over AI from the Service Provider; and (3) the way the acquired AI is stored in the Asset Information Model (AIM) [3]. The AIM's purpose is to be the single source of approved and validated information related to assets. The AIM's aim is to provide AI to help Asset Management (AM) functions make better decisions [4]. Within the AIM, the inventory module registers which assets an organisation has and the corresponding locations. This module contains AI that is mostly static and describes the assets' physical elements, such as name, location, length and width. This AI is often acquired during the AI handover. However, previous research has demonstrated that many Asset Owners are challenged during the AI handover to acquire the AI they require for AM decision making [1]. Unfortunately, when Asset Owners want to retrieve AI to inform AM decision making they often discover too late that crucial AI is missing because it was not acquired during the AI handover [2].

In sum, the bottlenecks within EIR specification have a negative chain reaction on the follow-up AI handover activities – AI acquisition and AI storage. The bottlenecks within EIR specification might be seen as the primary bottlenecks that constrain the AI handover process in providing the AI used for AM decision making. To improve the AI handover process there must be an emphasis on the importance of specifying accurate EIR within contracts [8].

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