A Framework for Developing Information Requirements for Built Asset Management Based on Organisational Sustainability Objectives

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Abstract.

Purpose- In recent years, digital transformation using Building Information Modelling (BIM) systems has reshaped asset management. This process involves systematically maintaining and improving assets throughout an organization's lifecycle, with a focus on sustainability objectives. However, the current asset management process often wastes time and resources searching for asset information. This research aims to create a BIM-based framework, address the disconnect between asset management models and key indicators of sustainability, and help achieve the organisation's sustainability objectives.
Methodology- This paper explores the relationship between asset management and sustainability objectives, establishing an integrated framework from existing literature. A seven-step approach to developing information needs is also proposed.
Findings- It was found that asset information requirements are often formed without a direct link to the organisational objectives they are intended to achieve or are difficult to detect adequately. Recognising the cyclical nature of asset management and BIM and generating a framework.
Implications- The framework will help address the disconnect between design aspirations and key indicators of sustainability.
Originality value- "The framework aligns asset management with sustainability objectives and integrates with BIM for a unified asset management platform.

Keywords: Building Information Modelling (BIM); Organisational Sustainability Objectives; Building Asset Management (AM)

1 Introduction

Asset information management throughout the lifecycle of built assets is gaining importance in both industrial applications and academic literature. Building Asset Management (AM) is guided by a series of industry standards that play an important role in all phases of the asset lifecycle (design, construction, operations and maintenance (O&M), disposal and renewal) (ISO 2014). The widespread use of Building Information Modelling (BIM) has led to significant improved project management during the design and construction phases, and there is a wealth of evidence that BIM increases productivity, reduces design and construction costs and improves risk management (Azhar 2011; Bryde et al. 2014; RIBA 2017). However, the use of BIM in O&M is relatively limited, and asset managers still face many challenges. For example, how to achieve sustainable development objectives (from three perspectives: social, economic and environmental), as well as more traditional technical and economic objectives, and how to obtain data and information that will contribute to the effective management of built assets and how to communicate them accurately and efficiently to asset managers (Kishawy et al. 2018). Exploring how to quickly and accurately communicate the information needed to achieve organisational objectives to asset managers will therefore be important in aligning asset management with organisational objectives.
From a social, economic, and environmental perspective there is a strong link between the long-term sustainability of buildings and effective built asset management (ISO 2014). It is therefore essential that organisational sustainability objectives are used as a key indicator for asset management. Therefore, organisational objectives (e.g., sustainability objectives) are translated into asset information requirements (AIR), which means identify all required assets and their management and maintenance procedures (ISO 2014). The basis for AIR is organisational information requirements (OIR). The OIR can clarify the organisation's needs, necessities and objectives, and organisational sustainability objectives are often included in the OIR (CDBB 2020). OIR is often in the form of a technical document and does not consider the changing environment. For this reason, the Centre for Digital Built Britain (2020) first introduced the Sustainability Information Requirement (SIR) to help achieve organisational sustainability objectives.
These information requirements are all part of the BIM process, defining the data, information and documentation required to operate and manage building assets throughout their lifecycle. Despite this, there are still complex

challenges to adopting BIM in the O&M phase, which are currently highlighted in the literature as follows:

The value of BIM in asset operations and maintenance is fundamentally poorly understood. the O&M industry is less receptive to emerging technological processes and practitioners still have a relative lack of data management skills (Ashworth et al. 2019).

Much of the research on achieving organisational sustainability objectives has focused on the planning and construction period, with the role of asset management often overlooked (Xu 2011).

Based on the challenges in the current literature, the following research question is proposed: 'How can BIM, asset management and requirements engineering be used to help set organisational sustainability objectives for asset information requirements?'

Overall, there are several challenges in the application of BIM in built asset management. The asset management process encompasses many activities, and these activities are accompanied by a wide range of information requirements. A standardized framework could simplify generating asset information requirements, aligning them with organizational objectives.

Therefore, this paper investigates an organisational sustainability objectives-led Asset Information Requirement （AIR） that will support BIM in the O&M phase of a built asset. The organisational key objective of sustainability in three dimensions - social, economic, and environmental - extends BIM as defined in ISO 19650-1 with the key element of an asset management system as given in ISO 55000. It also considers the addition of a sustainability objective as an intermediate step to assist in the development of the sustainability information requirements (SIR) from OIR to AIR.

The paper is structured as follows. Section 2 reviews the literature and industry standards in the field of built asset management and organisational sustainability. Section 3 describes how to develop a sustainability information requirement framework for asset management to align organisational sustainability objectives and asset information requirements. Section 4 summarises the findings future research opportunities and challenges.

2 Background

2.1 Sstandardisation of built asset management

Standardisation is important for organisations to strategically manage their assets. Such as ISO 55000 (ISO 2014) is considered the primary international standard for asset management. ISO 19650 (2018) is a specific standard for BIM in asset management, and there are other standards that do not directly describe the use of BIM in asset management but indirectly support information management in asset management. Other covering the maintenance and management of built assets include the Industry Foundation Class (IFC) standard ISO 16739 (ISO 2013). There are also ISO:29481, (BIM information manuals) PAS 1192:1-5, (data format specification) ect... Figure 1 demonstrates asset management's progression with standards towards clearer, more standardized practices. The study aims to forge a common framework that aligns AM, BIM, and sustainability objectives, establishing these standards as pivotal references.

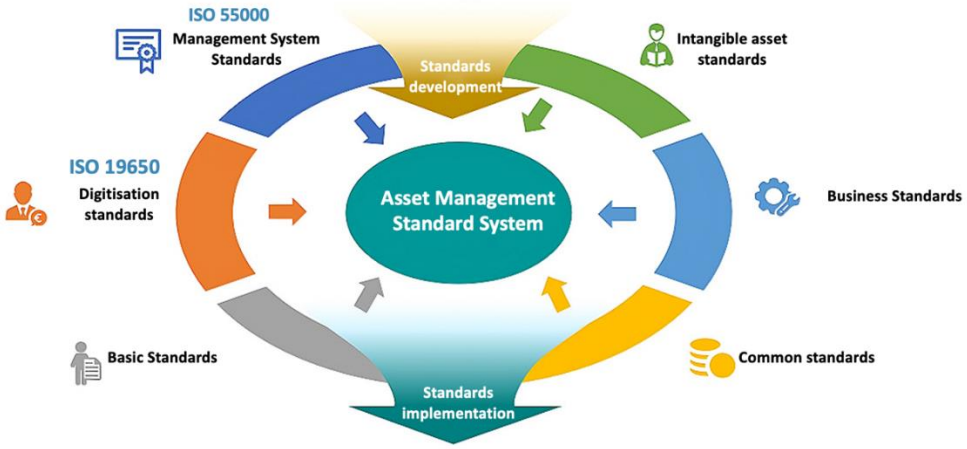

Fig. 1- The development of asset management standard system, Source: (author)

2.2 Built Asset life cycle Management

ISO 19650(2020) defines a built asset as a 'building, multiple buildings (e.g., a site or campus) or built infrastructure (e.g., roads, railways, pipelines, dams, docks, etc.) that is the subject of a construction project or

where the asset information is held in a digital format'. These assets are typically complex, necessitating comprehensive management for optimal operation and upkeep. Asset management is crucial for enhancing and adapting assets to support an organization's primary objectives (Atkin and Brooks 2009). The RIBA Plan of Work (2020) characterizes it as efficiently and effectively handling the entire lifecycle of assets.
The UK government's 2016 construction strategy references BIM and full lifecycle will provide a platform for smart city development and are key factors in increasing productivity and reducing operational costs (The Infrastructure and Projects Authority 2016). But most of the asset's life cycle is spent in the operations and maintenance phase, so the client and end-user are the ultimate beneficiaries of asset management (Eastman et al. 2008). Fig. 2 shows BIM's application through all project stages.

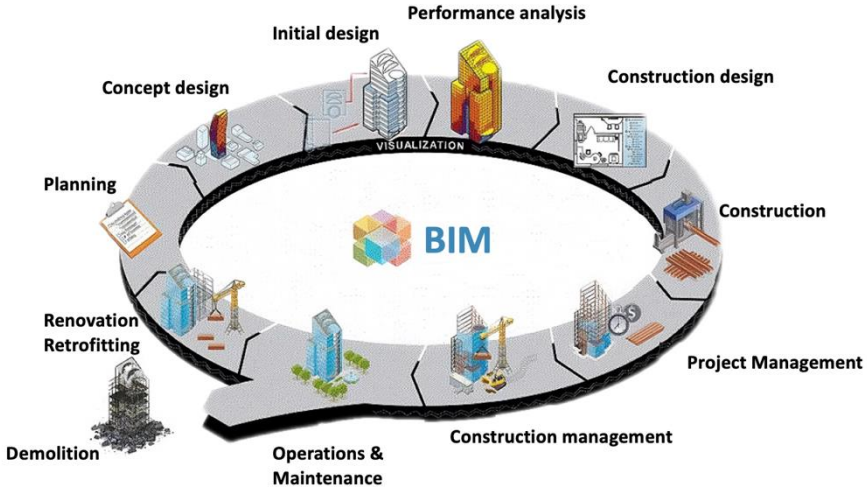

Fig. 2- Building Information Modelling (BIM) in building lifecycle, Source: (author)

To achieve efficient asset management during operations and maintenance, early consideration of space, occupancy, and maintenance requirements is crucial. In this phase, asset management teams spend significant time and effort gathering information from various sources, leading to redundant tasks that reduce productivity. While asset management is most pronounced during O&M, a holistic lifecycle approach is essential for enhanced efficiency.
Asset management during a building's lifecycle accounts for 60% of total lifecycle costs (Akofio-Sowah et al. 2014), making it a challenging and pivotal task. It impacts various operational measures from an asset lifecycle perspective. Asset design affects productivity and organizational goals (Haider et al. 2006). Lu et al. (2018) advocate considering sustainability throughout the built asset's lifecycle to gain a sustained competitive advantage. These studies imply that managing assets throughout the life cycle can help achieve the organisation's sustainability objectives.

2.3 Information management in built asset management

Information management system (IMS)

Information Management Systems (IMS) have become increasingly user-centric, with a focus on understanding users' requirements (Maguire and Bevan 2002). This has led to the emergence of Requirements Engineering (RE) for IMS development. Information management is crucial for effective built asset management, with BIM facilitating information development and requirements generation (Parn et al. 2017). ISO 19650 (2018) outlines a structured approach to information requirements in BIM-enabled asset management, with Figure 3 showing the hierarchy of Organizational Information Requirements (OIR) and its impact on information deliverables in the asset delivery phase, detailed further in Table 1.

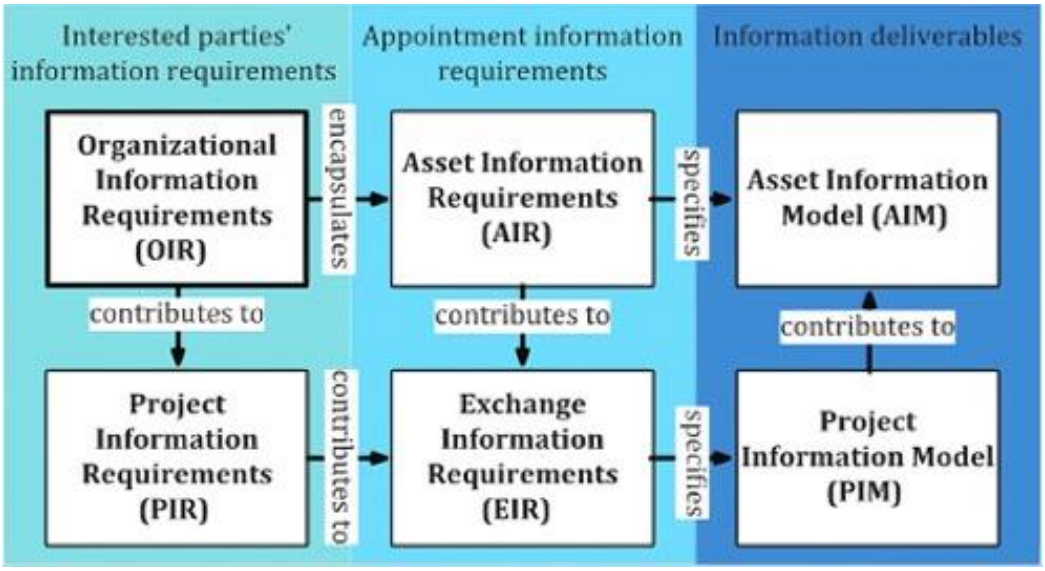

Fig. 3- Hierarchy of information requirement, Source: (ISO 19650)

Table 1- Explanatory table for Fig. 3, Source: (author)

OIR	To clarify the organisation's objectives
AIR	To be clear of all required assets, their management and O&M
PIR	What asset information should be provided for each project?
EIR	Establishing a clear agreement among stakeholders
AIM	Provide all data and information relevant or required for the operation of the asset
PIM	Information models developed during the design and construction phases of projects

Information requirement

ISO 19650 (2018) defines OIR as the information required to respond to high-level strategic objectives. Asset information requirements (AIR) are divided into three aspects: management, commercial and technical. The management and commercial aspects include information standards and production methods. The technical aspects answer the detailed information required for OIR. All AIRs should form a single coherent and coordinated set of information requirements. This study will focus on sustainability related OIRs and AIRs. Project Information Requirements (PIR) are the information requirements contained in the high-level strategic objectives of a project related to a built asset. The Exchange of information request (EIR) is like the AIR as a process of responding to and answering the PIR. All EIRs should also form a coordinated and coherent set of information requirements to address the PIR together.

Asset Information Modelling (AIM) is intended to be the single information source validated and approved associated with a particular asset. The main challenge is the complexity of capturing the OIR at the initial stage. Moreover, if AIR is not guided by organizational objectives, it will not be suitable for use in processes such as capital investment decisions, operations, and maintenance due to the diversity and uncertainty of asset management (Kiviniemi & Codinhoto 2014). The main challenge faced in making the jump from OIR to AIR is the organisation's objectives and requirements were not specific and quantifiable; the management team was not well versed in the technical aspects of operating and maintaining the assets; and AIR was developed from a technical perspective that did not fit well with risk management and asset management. (Heaton & Parlikad 2020). Heaton et al. (2019) first established an explicit link between AIR (operational level) and OIR (strategic level) by proposing Functional Information Requirement (FIR). This is to consider how to link organisational and asset management objectives so that asset management can efficiently serve organisational objectives. Ashworth (2019) argues that developing OIR and AIR will help asset managers improve asset management efficiency. But in fact,

will lead to more serious problems where the ideas of the asset manager will override the organizational objectives. Patacas (2020) suggests the adoption of the Information Delivery Manual (IDM) approach proposed by BuildingSMART (2018). IDM, as an ISO standard, emphasises information, data and models between different stakeholders at a given lifecycle stage, based on process mapping defined in the Business Process Modelling Notation (BPMN). While this approach integrates stakeholders and lifecycles, it may miss organizational objectives that are not explicitly reflected in specific activities. Therefore, it is necessary to find a standardized and common approach to fully integrate organizational objectives with AIR.

Sustainability Information Requirements

Organisational objectives determine the strategic need to acquire, maintain and use information related to assets. These objectives may be, sustainability objectives, profit objectives, technology objectives, etc. These objectives often change depending on the project and the organisation (Guo & Zhang 2022). This study focuses on sustainability objectives, which may be achieving net zero carbon emissions by 2030; reducing building costs by 20% by 2025; reducing reactive maintenance activities per asset by 5% by 2025, etc. (Lima et al. 2021). This again changes with organisations and assets.

The Centre for Digital Buildings UK (CDBB) (2020) proposes Sustainability Information Requirements (SIR) and defines them as information that contributes to the organisation's sustainability objectives. In the same way that sustainability objectives are sub-objectives of organisational objectives, SIRs are part of OIRs.

Figure 4 exemplifies SIR for environmental objectives, with specifics like performance data varying with different sustainability targets. Despite SIR's potential in reaching sustainability goals, literature on this is sparse.

Operation activity	Policy or external influencer	Information requirement	Information container	Exceptions	Acceptance criteria
Energy usage monitoring	• {Client's name} energy policy	• Actual building energy consumption (kWh/m2) • Building emission rate (kgCO2/m2) • Annual energy consumption (kWh per annum per m2 gross internal floor area) • Operational carbon dioxide emissions (tonnes per annum CO2) • Annual water consumption (litres per annum per m2 gross internal floor area or by per occupant) • Waste (tonnes per annum m2 gross internal floor area)	A spreadsheet (.xlsx)	N/A	Must adhere to standards.
Sustainability KPI	• {Client's name} energy policy	• Code performance • Sustainability performance • System specifications	• A spreadsheet (.xlsx) • Specifications in PDF	N/A	Must adhere to standards.

Fig. 4- Sustainability information requirements, Source: (CDBB)

IMS adoption in asset management, particularly for sustainability, is nascent with research gaps in Sustainability Information Requirements. Aligning asset information with organizational sustainability is tough due to:

Difficulty in integrating Sustainable Development Objectives into O&M phases.

Challenges in quantifying organizational requirements to inform AIR.

Technical support is still immature.

This study aims to overcome these by infusing Sustainability Information Requirements (SIR) and Sustainability Functional Information Requirements (SFIR) into the information hierarchy outlined in Fig. 3.

3 Sustainable requirement development methodology

3.1 Establishing the framework

The process starts with organisational objectives, identifies asset management objectives, and then helps with asset management, and the logical relationship matches that of Fig. 3. Therefore, if Fig. 5 can be combined with Fig. 3 and considers sustainability objectives, it will effectively address the aim of this study.

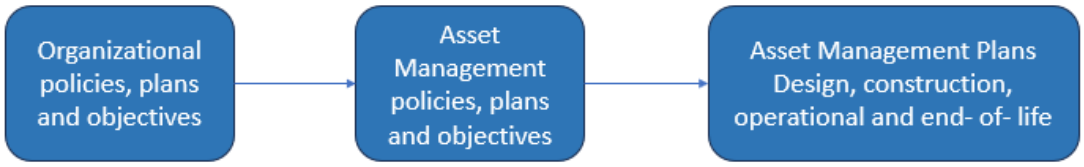

Fig. 5- General asset management process, Source: (ISO 55000)

A comprehensive literature review methodology was used and identified a knowledge gap in forming information requirements for organizational sustainability in asset management. Transitioning from OIR to AIR is a substantial step for many organizations, highlighting the need for an inclusive framework. To bridge this gap, a systematic method for producing sustainability asset information requirements is suggested, integrating SIR and SFIR for organizational alignment. Fig. 6 presents the expanded framework.

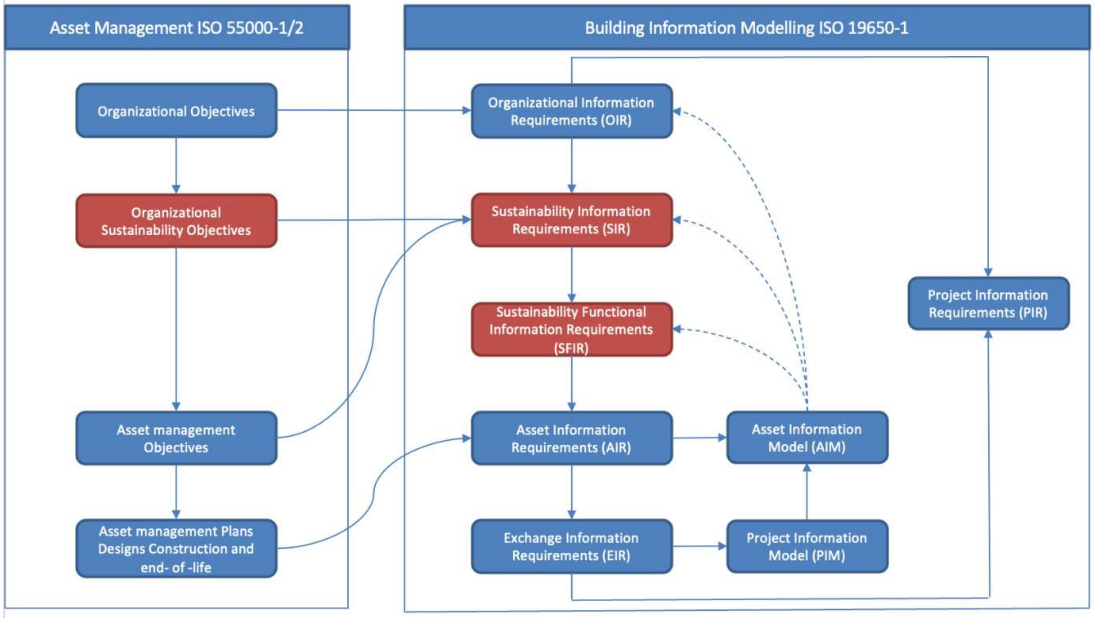

Fig. 6- Proposed framework for the information management relationships adopted from ISO 55000-1/2 and ISO 19650- 1, Source: (author)

The extended framework outlines a concise seven-step approach for information requirement development.

Step 1- Identify, Extract, and Classify Sustainability Objectives.

Step 2- Develop Functional Information for Sustainability Assets.

Step 3- Create Organizational Information Requirements (OIR) and derive Sustainability Information Requirements (SIR) aligned with objectives.

Step 4- Establish Sustainability Functional Information Requirements (SFIR) to address OIR and SIR questions.

Step 5- Develop Asset Information Requirements (AIR) and a complete AIR flow chart.

Step 6- Validate Information Requirements through stakeholder surveys.

Step 7- Document the developed information requirements.

3.2 Proposed research approach- next steps for data collection

In this framework, organizational sustainability objectives should rely on primary data and adapt as needed, possibly through a questionnaire.

Questionnaire Design

Given the sustainability focus, the questionnaire should cover economic, social, and environmental aspects. Use the Likert scale for assigning values based on observable indicators. A standardized questionnaire serves as the foundation, with the first part collecting general respondent information (excluding personal data). The second

part lists organizational sustainability objectives from literature, policy documents, and interviews, asking respondents to rate importance on a five-point scale (1 to 5) based on their experience. Sustainability objectives are selected based on collected data.

Sample

Administer the questionnaire through web surveys, emails, and telephone interviews, targeting asset management stakeholders and researchers. Three methods identify the sample: 1)Literature Analysis: Initial stakeholder identification through relevant studies and reports. 2)Expert Judgment: Experts interview and screen the initial results. 3)Case-Specific Application: Apply the framework to specific building assets, involving academic discussions to determine the final sample.

4 Conclusion and future research

4.1 Conclusion

This research introduces an information requirement development process guided by traditional Requirements Engineering and the emerging BIM information system, focusing on organizational sustainability objectives. Early IMS often overlooked this aspect, leading to operational performance decline. The adoption of IMS in building asset management lags other areas, with limited research on sustainability objectives. However, industry standards offer inspiration.

This research extends the information management relationship between asset management and BIM (see Fig. 3). It aligns OIR with organizational objectives, introduces SIR and SFIR to integrate sustainability objectives into asset management, and proposes a seven-step approach for information requirement development.

The framework bridges the gap between design aspirations and sustainability indicators, aligns asset management with organizational objectives, and is standardized and repeatable. It not only integrates AM and sustainability objectives, aiding AIM development but also incorporates lifecycle concepts to support information requirement development throughout the lifecycle.

4.2 Future research

Future research could focus on whether the framework can be linked to BIM models to provide an integrated asset management platform and on the feasibility of interoperability in terms of how information is stored throughout the process.

4.3 Limitation

Although the research provides an overall framework for the development of AIR. However, it still has limitations in its implementation. Organisational objectives are often dynamic, and the framework does not consider changes in policy and environment. So further consideration is still needed in the future.

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