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EXPLORING THE ENTERPRISE BIM CONCEPT IN PRACTICE: THE CASE OF ASSET MANAGEMENT IN A NORWEGIAN HOSPITAL

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SUMMARY*: Organizations face challenges in utilizing Building Information Modeling (BIM) for digital Asset Management (AM), as BIM from the design and construction phases often proves to be of limited use for AM. To address this, the concept of Enterprise BIM is introduced with the aim of organizing BIM activities throughout the lifecycle in line with the organization's operational and strategic needs. The article explores the current industry practices of implementing Enterprise BIM for effective AM support. It focuses on Vestfold Health Trust and its award-winning hospital project in Toensberg, Norway, which was notable for its use of Integrated Project Delivery (IPD) and its attempts to adopt Enterprise BIM methodologies and solutions. Through literature studies and interviews with fifteen key personnel, the article provides recommendations for significant improvement within several AM areas, such as expertise, technology utilization, standardization, solving end-users' information needs, ontological adaptation, and associated IT solutions needs. The results highlight the limitations of using the Industry Foundation Classes (IFC) schema and format for AM applications and suggest the development of flexible, searchable solutions based on ontologies and semantics to integrate sensor data into digital twins and asset information models. The study reveals a competency gap and deficiencies in information processes and IT solutions that organizations, along with the industry, must both address, emphasizing the use of international standards such as ISO 19650 to improve the integration of value chain considerations. Overall, this article provides valuable recommendations and a roadmap for the more strategic, holistic, and sustainable management of building information that aims to take into account and satisfy the end-user's information needs.*

KEYWORDS*: Asset Information Model, Asset Management, Building Information Modeling, Digital Twin, Enterprise Architecture, Enterprise BIM, Level of Information Need.*

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1. INTRODUCTION

Despite progress in digitalizing and use of building information modeling (BIM) in design and construction, the architecture, engineering, construction, owner, and operator (AECOO) industry is struggling to extend this digitalization to operational processes both efficiently and sustainably (Patacas et al., 2020; Love et al., 2015; Zadeh et al., 2017; Munir et al., 2021; Smith and Tardif, 2009). Interdisciplinary needs for the flow and linking of digital building information across domains necessitate enhanced interdisciplinary integration (Whyte and Hartmann, 2017). Furthermore, a significant challenge arises when systems employed during the design and construction phases do not align with those used in the operational phase, leading to the underutilization of gathered information and a wasteful expenditure of time and resources (Sacks et al., 2018; Koch et al., 2019).

Reasons for the discontinuity of information flow from the design and construction phases to operations include the existence of barriers to the traceability of construction materials (Mohn and Lohne, 2022), siloes (Lohne and Mohn, 2022) and a significant lack of standardization that defines uniform information requirements across the assets' value chain (Malla et al., 2023; Godager et al., 2022). In addition, to improving information processes, supported by fully reaping the benefits of technological innovation, parallel innovations in processes and policies are essential. Specifically, in addressing lifecycle information management challenges, adopting the Lean, Agile, and integrative production methods of the manufacturing and software industries can yield valuable lessons and significant advantages (Mehran et al., 2022; Succar and Poirier, 2020; Boton et al., 2018). Furthermore, clear identification and communication of the information needs of end-users across various roles and functions during the operational phase is deemed a precondition for succeeding with further digitalization (Teicholz, 2013; Godager et al., 2022).

The asset value increases at every stage, from design innovation to sustainable disposal, through optimized construction and management for stakeholder and social benefit (IAM, 2015). Simultaneously, the core business and asset management (AM) face continuously evolving demands from society, tenants, and users of buildings and must increasingly become service providers (Lenton et al., 2022), thus needing to focus on the adaption of open innovations and enhanced value creation for clients (Chesbrough, 2011). Modern AM involves developing, implementing, operating within, and continuously improving AM programs and systems. Active participation in these systems is vital for their success. Asset managers need to understand the intricacies of these programs and remain agile in implementing them. This includes ongoing portfolio analysis, real-time adjustments based on market movements, and direct engagement with clients to understand their evolving needs and objectives (IAM, 2015). In addition, asset managers need to solve the industry's hitherto inadequate response to the green shift, as shown by products and equipment that are vital for a building's sustainability in AM currently being inaccessible (Mohn and Lohne, 2023).

The increased performance needs to reinforce the necessity for flexible IT solutions to manage the desired information processes. Recognizing this, the International Organization for Standardization (ISO) has issued the recent ISO 19650 series of standards, which are aimed at improving the digitization of asset value chains, mainly by proposing a framework for information management (ISO, 2018b; Borrmann et al., 2018). This standard is expected to have a significant impact on supporting digitalization across the AECOO industry lifecycle (ISO, 2018b; ANZGuide, 2019; Godager et al., 2022; El-Din et al., 2022; Malla et al., 2023). In contrast, little research has comprehensively explored ISO 19650's potential to support AM. In particular, the management of assets in asset information models (AIMs) throughout the operational phase is considered to benefit from an increased application of the standard's part three (ISO, 2020).

To use information more efficiently, it is necessary to connect and organize building information according to AM's requirements and the organization's needs, including its physical assets and digital information. Such bridge-building is the main goal of the Enterprise BIM concept (Godager et al., 2021; Godager et al., 2022) (see Figure 1). Enterprise BIM strives to develop holistic framework to streamline and offer a comprehensive digital building and infrastructure information support tailored to AM's business needs throughout the assets' value chain. With the increasing need to strategically manage portfolios of buildings at different stages of their life cycle, the industry needs standardized frameworks and associated IT solutions that enable the desired information flow. To facilitate AM information flow and sharing, a Common Data Environment (CDE) is essential for 1) delivering information models from distributed data sources, 2) validating these models against requirements, and 3) utilizing the information (ISO, 2018b; Patacas et al., 2020). Due to current knowledge levels, deficient and non-standardized processes, and often high levels of complexity, studies show that organizations need help in establishing comprehensive and standardized processes for information flow and reuse (Succar and Poirier, 2020; Dossick et al., 2023). In addition, contracts are largely unclear due to a lack of expertise (Sriyolja et al., 2021).

At the same time, Facility Management (FM) is a more commonly used term than AM, with FM practices mainly being carried out through analog methods in relation to the physical building. ISO 55 000 (ISO, 2014, p. 14) defines AM as "the coordinated activity of an organization to realize value from assets." Additionally, AM aims to balance and optimize the costs, risks, content, business, and performance of assets across their value chain (Pocock et al., 2014). Despite this, efforts to integrate AIM more closely with AM often face challenges, primarily due to an organization's lack of holistic strategy and understanding (Vass, 2015).

Forward-looking asset managers aim to improve operations using IT technologies such as BIM, Geographical Information Systems (GIS), digital twins, Internet of Things (IoT), Artificial Intelligence (AI), and augmented reality (AR) to enable direct, structured stakeholder communication (Isikdag, 2015; Han and Crespi, 2017; Dave et al., 2018; Tang et al., 2019). Utilizing IoT enables the use of Semantic Web technologies and hybrid approaches to optimize real-time building performance monitoring and assessment (Tang et al., 2019). At the same time, these technologies require purpose-driven strategies and sufficient knowledge among asset managers, which research shows is lacking. On the other hand, AM shows little interest in semantic technology as a platform (Godager et al., 2021). The demonstrated challenges show that the AECOO industry has a long way to go in solving the necessary obstacles. Currently, only analog processes are translated into digital, and new contract types and processes are not adapted to new technologies (Labonnote et al., 2021).

Acknowledging today's significant gap in achieving full Enterprise BIM functionality, the two research questions and objectives of this article are:

1) What is the industry's current adoption of the Enterprise BIM mindset?

2) What are the suggested future necessary development steps to achieve sustainable Enterprise BIM in AM?

Highlighting the necessity of aligning research with practical application, the article refers to the previously defined Enterprise BIM concept and framework by Godager et al. (2021) and their further developed and standardized Enterprise BIM framework (Godager et al., 2022). To address the research questions reliably, the article combines extensive literature studies with a case study of an innovative hospital implementing an Enterprise BIM approach. The case study at VHF was selected because of its dedication to Enterprise BIM, international accolades, and use of Integrated Project Delivery (IPD) in its seven-stage construction program. Vestfold Hospital Trust (VHT) covers all hospital locations in Vestfold County, while the recently concluded Toensberg Project is part of Toensberg Hospital. The Health Trust's global recognition, including the buildingSMART International Award for advanced openBIM design (BSI, 2017) and the 2020 Handover Prize (BSI, 2020), motivated the selection of the study. The case study uses interviews with key organizational roles to investigate strategies, current challenges, and the status of in Enterprise BIM implementation in supporting AM and end-users' information needs (See Appendix for details). This case study, together with extensive literature research, forms the basis for a further assessment and discussion of the results achieved from a broader perspective so that this can benefit and develop the entire AECOO industry. The study contributes to an increased understanding of the AECOO industry's needs for digital requirements in projects to support AM holistically. The study also assesses the industry's untapped potential for exploiting ISO 19650 to develop digital purpose-driven AM by strongly emphasizing end-users' "level of information needs" (LOIN) in information requirements and enterprise systems.

The next section provides a theory about Enterprise BIM and its relation to AM. Section 3 clarifies the research methodology. Section 4 shows the case study's results. Section 5 discusses the results and suggests further steps to reach the goal of Enterprise BIM. Finally, Section 6 provides some concluding remarks.

2. AM AND ENTERPRISE BIM

AM is a systematic approach to governance that realizes all the values, both material and intangible, for which a group or unit is responsible throughout the entire value chain. The values should be based on the needs and expectations of its stakeholders. Therefore, AM includes a systematic process of developing, operating, maintaining, upgrading, servicing, and disposing of assets cost-effectively (including risks and performance attributes) (ISO, 2014). In the context of Enterprise BIM, material assets (physical objects, complex processes, infrastructures, buildings, or equipment) are the most prominent.

AM and FM have developed as two distinct management disciplines, each with their own standards and language of preferred terms, despite both being concerned with managing an organization's physical assets and services (ISO, 2020). However, for simplicity's sake, the main body of this article considers these two disciplines as one. Accordingly, it uses "AM" to denote both, similar to the ISO 19650 standard (ISO, 2020). AM has evolved through the new thinking on the value-driven management of assets (Lloyd and Corcoran, 2019) and the optimization of returns by efficiently allocating and utilizing assets to balance performance and financial constraints (Konstantakos et al., 2019). Properly AM practices are particularly business-critical in asset-intensive organizations, with significant challenges regarding the increasing demand for service and stakeholder expectations (Sacks et al., 2018; Pishdad-Bozorgi et al., 2018). Despite targeted efforts to utilize building information in AM, studies show several remaining challenges. Matarneh et al. (2019) refer to inadequate information requirements, lack of information from converting captured as-built data, information updates, the handling of uncertain data and objects and their relationships to existing buildings, and applications that could be more user-friendly. Lenton et al. (2022) highlight that assets are managed informational silos because of system interoperability issues, causing user frustration, poor decisions, and a fragmented view of assets' entire lifecycles.

The Enterprise BIM mindset connects asset information models (AIMs) to support holistic and sustainable AM (Godager et al., 2022; Godager et al., 2021). It seeks to develop necessary information frameworks and become the digital basis for a comprehensive approach that meets the entire spectrum of a business's information needs along the entire value chain of assets. Furthermore, Enterprise BIM intends to develop a complete information framework that meets an enterprise's information needs for assets throughout the value chain, thereby enhancing digital asset information for AM support (Godager et al., 2022). Developing such a framework requires integration of people, technology, and processes to achieve the organization's strategic goals. At the same time, while Enterprise BIM provides an organization with important information about its physical assets, it is ultimately up to the organization to decide the extent of Enterprise BIM's application. To address and support AM's information needs, Enterprise BIM needs to standardize processes and develop customized information requirements. Figure 1 depicts the connection between asset management (AM) and Enterprise BIM, illustrating how digital information on physical assets supports AM through defined information requirements. Enterprise BIM's goal of helping AM with digital asset information depends on adopting standards and developing tailored information requirements.

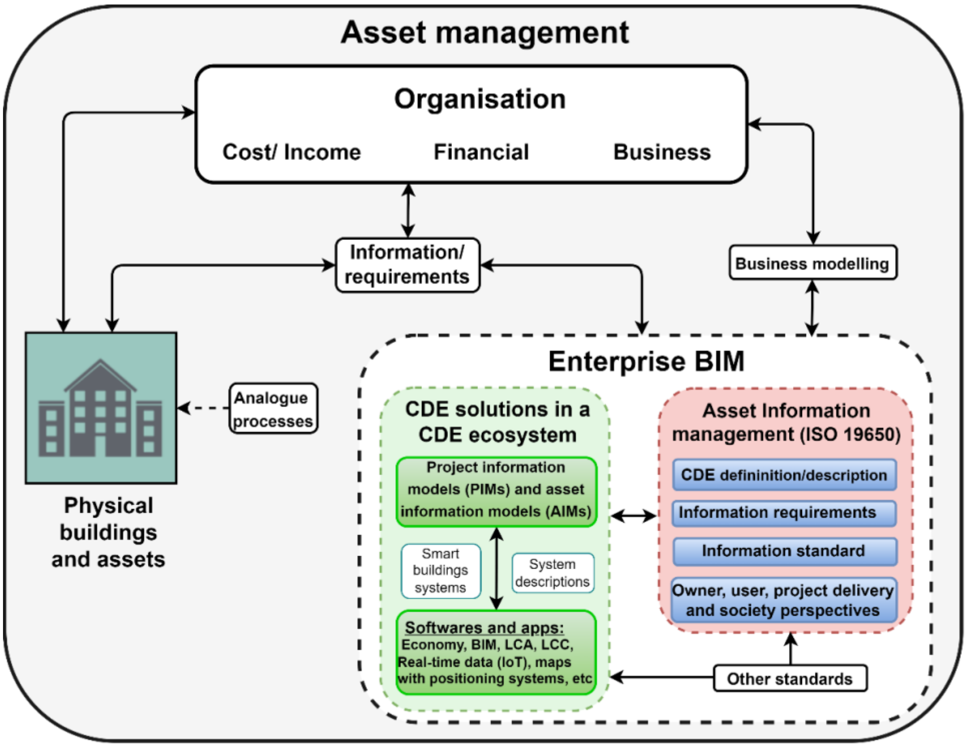

Figure 1: The link between asset management and Enterprise BIM (Godager et al., 2022).

In order to meet AM's information needs, Enterprise BIM must standardize processes and adapt the information requirements (see Figure 1). Furthermore, effective Enterprise BIM requires robust and adaptable CDE solutions for end-to-end asset information management, usually necessitating multiple CDE solutions that together form a CDE ecosystem. This CDE ecosystem is essential in facilitating digital interactions and managing information across the entire value chains of built assets, thus improving interoperability (Patacas et al., 2020; Godager et al., 2022; Godager et al., 2021). Enterprise BIM benefits from building on the groundwork laid by ISO 19650 Parts 1 (ISO, 2018b) and 2 (ISO, 2018c) for project delivery, with Part 3 (ISO, 2020) being particularly critical for the operational phase. It underscores:

- The importance of managing digital information to meet the enterprises' various information needs.
- The emphasis on supporting sustainability and environmentally friendly building practices.
- The importance of the links between new and existing enterprise systems.

As enterprises encounter growing complexities and uncertainties, the adoption of business modeling or enterprise architecture (EA) is becoming increasingly essential. EA aids organizations by directing the design of adaptive and resilient businesses and their information systems, equipping them to navigate challenging conditions effectively (Lapalme et al., 2016).

The complexity of Enterprise BIM underscores the urgent need for an open, standardized framework to guide the consistent management of digital building information across asset lifecycles. This, alongside ontologies detailing the information needs of diverse end-users, is a critical requirement. The Zachman Framework (Zachman, 2011) is a recognized EA model that provides both an ontological schema of architectural artifacts and a taxonomy used to structure and analyze enterprise components, effectively guiding and connecting various perspectives to address IT-related challenges (Lapalme et al., 2016). Introduced in 1987, the Zachman framework is a comprehensive classification schema for enterprise architecture, emphasizes the integration of processes, information, and systems (Zachman, 2008). It offers a logical overview essential for controlling information and leveraging it to steer and evolve an organization (Zachman, 2008). To gain a comprehensive understanding of Zachman's "what," "how," "where," "who," "when," and "why" classifications from all perspectives/viewpoints in Enterprise BIM, Godager et al. (2022) developed a customized and extended framework based on Zachman (Zachman, 1987; Zachman, 2008). This framework adds and demonstrates three fundamental additional perspectives in ISO 19650 that are of great importance to Enterprise BIM that must be treated separately: B. Society, D. Project delivery or AM and E. End-user (see Figure 2). By adding these perspectives, Zachman's framework can also be applied to buildings and infrastructures, their use and for societal information needs. The framework facilitates informed decisions for the enterprise's creation, operation, and transformation by adopting a "multi-perspective" approach, which integrates diverse stakeholder viewpoints into a comprehensive architectural overview.

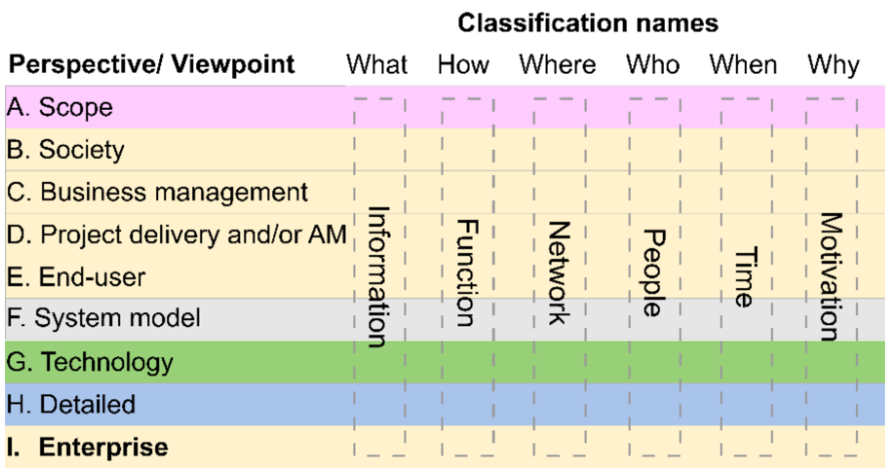

Figure 2: Simplified, customized Enterprise BIM framework built on the Zachman framework.

Below explains the main essence in the different Enterprise BIM perspectives which also are used to organize the results in Section 4.

A. Scope

The scope of the Enterprise BIM concept is holistic in its motivation and approach to sustainability throughout the entire value chain of assets by bridging people, technology, and processes to reach the organization's strategic goals. Furthermore, the scope covers key areas, such as (1) selecting appropriate suppliers, products, and materials, including descriptions of the asset information model (AIM), (2) measuring, optimizing, and maximizing the suitability, utilization, and performance of existing assets, (3) reduce rework and unnecessary resource input, energy consumption and waste, (4) optimize health and safety, and well-being.

B. Society

The CDE ecosystem must report the necessary information according to the society's requirements (UN Sustainable Development Goals, political decisions, laws, spatial plans, building permits, and concessions with high performance, fewer resources, and lower risk).

C. Business management

Business management includes establishing, maintaining, and developing the asset's or project's purpose and making strategic business decisions (Smith and Tardif, 2009). The ISO 19650 framework, which can guide the implementation of AIM, provides recommendations that contribute to developing clear and standardized collaborative approaches and information processes throughout the life cycle of built assets (Godager et al., 2022; ISO, 2020). In addition, ISO 19650 guides the level of information need (LOIN) framework and enables targeted information requirements and guidelines for using CDE. The interaction and information flow between CDE solutions are essential for coordinated business management.

D. Project delivery and/or AM

Handling project deliveries (project information models) and facilitating value-creation for owners and users in AM requires establishing CDE processes and one or more CDE ecosystems where information management (information requirements, deliveries, and sharing) occurs. Property teams want a sustainable digital transformation combined with operational and performance understanding and improvements while taking greater responsibility for strengthening the financial results.

E. End-user

End-users include everyone in the organization who uses IT at all levels. Therefore, digital processes must have an end-user focus to become profitable. The information needs of these end-users should determine the required information in AIM, while many AM roles may only require limited access to design and construction-phase information.

F. System model

The enterprise's overall situation must be considered, including relations between strategic goals, business rules, work processes, organizational structures, products, services, and IT infrastructure (Sandkuhl et al., 2014). Furthermore, achieving efficient, humane, and environmentally responsible EA in the context of ever-increasing complexity is challenging (Lapalme et al., 2016). Therefore, from a Zachman perspective (Zachman, 2011), EA will contribute to helping and guiding the development of businesses and their information systems.

G. Technology

The technology model structures the information system and configures data and information flows within a CDE ecosystem, aiming for automation to enhance profitability. It connects the owner's wishes with the builder's execution, ensuring implementers' efforts align with strategic objectives and stakeholder needs, thus informing rule design. Furthermore, semantic completeness in control systems like sensor networks is vital, necessitating the development of a scalable semantic approach that accommodates dynamic data (Boje et al., 2020).

H. Detailed

Designing the physical data model and determining its process configuration must be done from a detailed technical perspective. Technical component input (programs, codes, manuals, procedures, and links) and end-user architecture must be implemented in CDE solutions. In addition, the security architecture must be established, including role-controlled access specifications and responsibilities, as well as timing and rule specifications.

From a holistic perspective, this smart enterprise AM ecosystem brings together partners utilizing interoperable and innovative technologies such as IoT, AI, 3D scanning and BIM, digital twin, e-procurement and supply chain, and Big Data analytics (Lenton et al., 2022). In this article, a digital twin is defined as a chosen digital representation of an intended or actual physical building unit, system, or process that acts as its effectively inseparable digital counterpart for defined practical purposes, such as simulation, integration, testing, monitoring, and maintenance.

I. Enterprise

The enterprise perspective results from the entire architecture, whereby the established Enterprise BIM CDE ecosystem can support the organization's information needs. It is here that the functional interaction between people, technology, and processes occurs. In this end-user environment, the goal is to achieve interaction between an updated AIM and AM's core business (Godager et al., 2021; Godager et al., 2022; Pocock et al., 2014). Geographical information systems (GIS) also provide valuable support for improved AM (Boyes et al., 2017). Furthermore, the operationalization of "Smart Enterprise AM" (Lenton et al., 2022) in well-founded AIMs linked to enterprise systems must be established, such as using sensors and the Internet of Things (IoT) in specialized digital twins (Heaton et al., 2019). The ideal solution is an AIM with "bi-directional" data and information exchange links with other enterprise management systems (Ashworth, 2020).

3. METHODOLOGY

The purpose of this study is to evaluate the current situation, obstacles, and remedies for using digital asset information for Enterprise BIM. Few theoretical and practical studies follow an Enterprise BIM mindset, so the article has used a combination of adjacent literature studies and an embedded case study of current practices, following Saunders et al.'s (2019) qualitative case study guidelines. The case study approach was used because it can provide detailed contextual insights (Yin, 2018; Tellis, 1997) and allow for in-depth examination of experiences and challenges, bridging theoretical and practical domains (Corley and Gioia, 2011). Choosing an embedded case study allowed for a more detailed and complex exploration of the research questions, providing insights into various facets and allowing several components and units of the organization to be examined (Yin, 2018; Saunders et al., 2019). This approach is particularly useful for complex cases like this one, where the interactions between different components are significant. Figure 3 shows the different steps of the research process, starting with literature studies to establish the current state of research and prepare for the case study.

Thirteen key roles at VHF (see Table 1) were carefully picked out as informants in cooperation with the hospital organization to acquire a holistic understanding through diverse expert insights. These roles covered the delivery and operational phases related to the new building project. The interviews were aimed at answering the research questions by garnering sufficient saturated data insights from both project (including project leader, BIM coordinator, consultants, and contractors) and operational leaders (encompassing property management, technology, FM, cleaning, textiles, electricity, and data-assisted construction). To enhance the scope of the study and ensure data saturation, a comparative analysis was conducted involving two BIM coordinators from St. Olav's Hospital, a pioneer in Enterprise BIM and IT solutions since 2015.

All interviews were conducted semi-structured, guided by a specific interview framework (see Appendix). The interviews ranged from thirty minutes to two hours, depending on the informants' insights relevant to answering the interview and research questions. They were conducted both in person (five) and via Microsoft Teams and were descriptively analyzed using NVivo. This process included transcription, coding, the deletion of recordings, and the validation of responses to align with research objectives, ensuring rigorous analysis based on predefined categories.

The ethical considerations for this study were meticulously planned and approved by the Norwegian Agency for Shared Services in Education and Research (NSD, 2022). This comprehensive approach encompassed informed consent from all informants, privacy, and ethical data handling, ensuring the highest standards of research ethics. Interviewees were briefed on the study's scope, data usage, and procedures, resulting in NSD-standard consent forms and the opportunity for participants to review the manuscript and provide feedback. This comprehensive approach to data collection and analysis contributes to instill confidence in the thoroughness of our study.

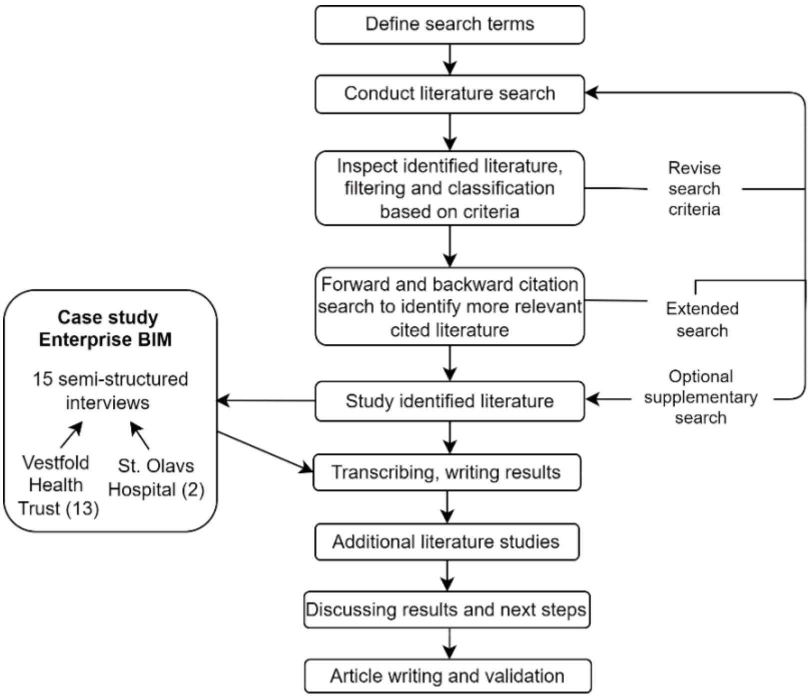

Figure 3: The research process.

Secondary sources for the study included a master's thesis on Integrated Project Delivery (IPD) in Norway (Skoglund and Simonsen, 2019) and online project information supplementing the primary data collection from literature and interviews, following the guidelines recommended by Saunders et al. (2019).

Given the AECOO industry's early stage of engagement with the Enterprise BIM mindset and in agreement with Roger's (2003) diffusion of innovation theory, the study used an exploratory strategy to assess current practices and future development needs. The structure of the Zachman-based Enterprise BIM framework (see Section 2) was chosen to support the article's exploration due to its suitability for managing complex, distributed systems (Sessions, 2007). Thus, it facilitates a holistic approach to Enterprise BIM and covers all its perspectives (see Figure 2).

The literature searches used the search terms "Enterprise BIM", "asset management and BIM," "enterprise architecture and BIM," "Facility Management and BIM," "ISO 19650 and BIM," "digital twin and buildings," "IoT and BIM," "Common data environment and asset management," "enterprise architecture and BIM", "semantic web and BIM," and "IPD and BIM", as well as related terms to identify pertinent sources. After the case study, additional literature research refined and validated the findings, guiding the discussion for further steps for Enterprise BIM.

3.1 Description of Case Study

Vestfold Health Trust belongs to the Southern and Eastern Norway Regional Health Authority, and its 5300 employees provide health services for 250,000 residents. The health trust recently completed an innovative hospital project covering 45,000 m2 and has digitized its 160,000 m2 portfolio of existing buildings.

The extensive use of project information models and digital tools has been an important part of the Toensberg project. All actors have used a common computer platform, document management, and follow-up system. For example, the project has used Jotne's BIM server (Jotne), based on buildingSMART's openBIM, for information management purposes. That means the information workflow was created exploiting the Industry Foundation Classes (IFC) schema and format (BSI, 2017; Aarseth, 2020; ISO, 2018a). In 2017, the project won buildingSMART International's award for developing a system and product register connected to the BIM model used in hospital operations (BSI, 2017).

The latest projects have the most extensive building information modeling (BIM) integrations for AM. However, the health trust has digitized its entire existing portfolio (84 buildings at 23 locations), at least at the simplified BIM (SlimBIM) level, where the data capture typically originates from existing drawings or scans. Figures 4 and 5 show the planned BIM technology map for the project and the handover workflow (Aarseth, 2020), including using the IPD contract. Figure 4 outlines the BIM technology roadmap for the Toensberg project at VHT, highlighting the core principles of virtual desktop infrastructure (VDI) and detailing the handover process on the right side (Jotne, Aarseth, 2020). The process of handing over is more detailed in Figure 5. At the same time, these technology maps illustrate a workflow that is heavily reliant on the IFC format for various software tools to interface with the Jotne BIM server.

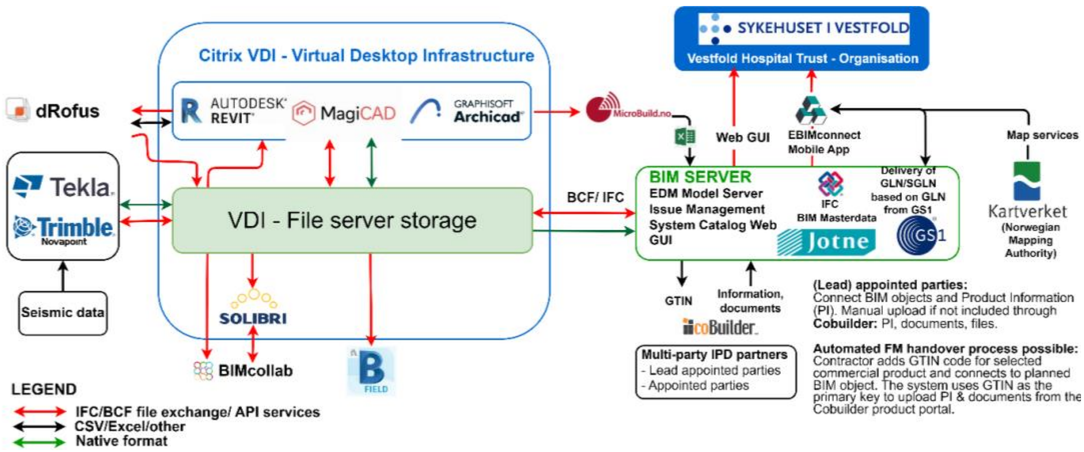

Figure 4: Planned BIM technology map description for the project and the handover in the Toensberg project at VHT (Jotne, Aarseth, 2020).

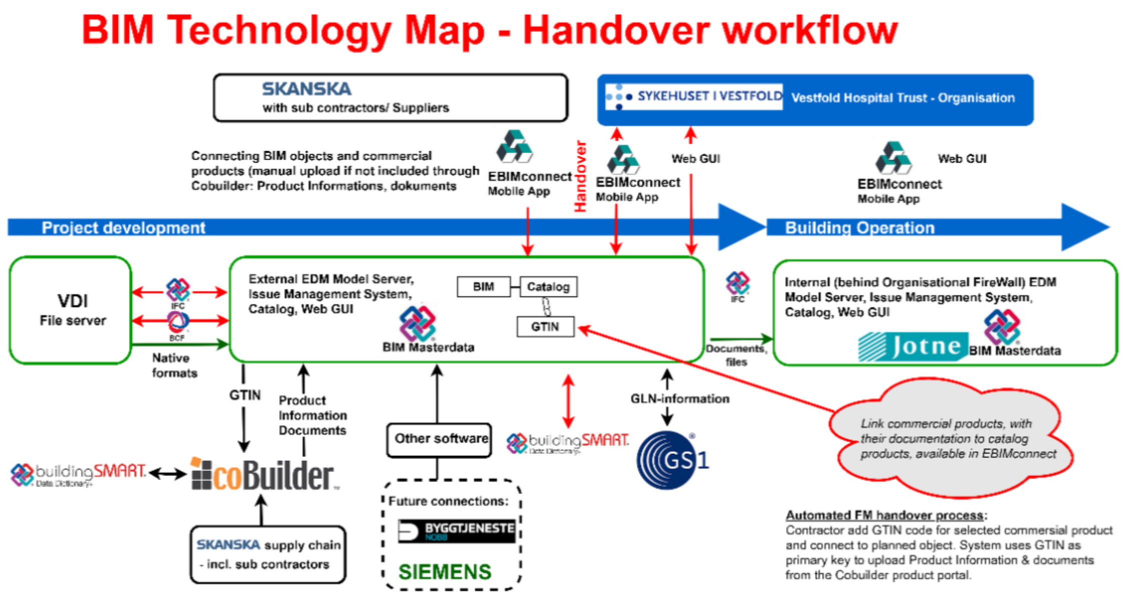

Figure 5: BIM technology map for handover workflow in the Toensberg Project, mainly covering the right side of Figure 4 (Jotne; Aarseth, 2020).

Table 1: Key roles at VHF.

Informant number	Role/Work position	Year of relevant experience
I-1	Property manager, Vestfold Health Trust (VHF)	30
I-2	Housekeeper, cleaning manager, VHT	20
I-3	Leader quality, textiles and cleaning, VHF	9
I-4	Director FM and service, VHF	19
I-5	Electrician, VHF	5
I-6	Technology director, VHF	19
I-7	DAC operator, VHF	20
I-8	BIM coordinator, project, and VHT	10
I-9	Project manager, project	22
I-10	Project planning leader: contractor (lead appointed party), project	12
I-11	Project leader: electrotechnical installations, project	28
I-12	Project leader: consultant engineering (member of the multiparty consulting and architect group, Cura), project	9
I-13	Enterprise architect, external	29
I-14	BIM coordinator 1, St. Olav's Hospital	7
I-15	BIM coordinator 2, St. Olav's Hospital	2

4. RESULTS

This section presents the results from the selected case study based on the semi-structured interviews and the document analysis. Important parts of the interviews deal with considerations related to information processes and information management. The results include assessments of the suitability of the handover results and views on integrating new and existing building information into the organization's Enterprise solutions. For purposes of categorization, the analysis uses the structure and perspectives from the developed Enterprise BIM framework (Godager et al., 2021; Godager et al., 2022) shown in Figure 2. This approach tests the framework's logical order, where each perspective builds upon the previous one, culminating in the comprehensive Enterprise perspective that encompasses all others.

A. Scope

The Vestfold Health Trust prioritizes patient care, so its buildings must ensure operational reliability, resilience, and stability, as well as the ability to address both foreseen and unforeseen events swiftly. I-1 mentioned that the Health Trust has developed detailed Asset Information Models (AIM) for newer buildings and simplified 3D geometric AIMs for its 84 buildings across 23 locations, underlining a strategy that all buildings have functional models. This approach led to setting ambitious information requirements in the Toensberg project to bolster AM.

Informants I-6, I-8, and I-9 noted that the Toensberg Project's construction contracts required Enterprise BIM, integrating all data into their Enterprise BIM solution. Due to the difficulties in finding a suitable Enterprise BIM solution, the Health Trust collaborated with the Jotne Enterprise solution's supplier to tailor functionalities to their needs (I-6). I-1 revealed that the IPD contract necessitated all product documentation in the Jotne Enterprise openBIM solution, including open BIM models with integrated FM information. The project emphasized utilizing the GTIN for purposes of product identification, aiming to adopt the Electronic Product Code Information Services (EPCIS) standard for supply-chain visibility (I-8, I-9).

However, Enterprise Resource Planning (ERP) systems are not yet integrated with the Jotne solution as desired (I-1, I-6, I-8, I-9), and digital 2D solutions for cleaning support have not been incorporated into the BIM server solution (I-1, I-2, I-3, I-6, I-9). This has led to ongoing searches for a more suitable Enterprise BIM solution for AM needs, with criticality identified as a key challenge and future priority (I-8, I-9). Despite being a strategic organizational focus, digital twin applications in the AECOO industry are still in the early stages, with IoT and machine-learning plans still under development (I-6, I-9). Consequently, the strategy now includes updating models for selected products and preparing for future progress in available enterprise solutions (I-1, I-4, I-6).

I-1, I-4, and I-6 acknowledged that the Health Trust's financial investment has primarily targeted new projects rather than operational phases, signaling a need for change. Enhancing the organization's competence in adopting and understanding new technologies is critical for this shift (I-6).

B. Society

Currently, reporting European Union and United Nations sustainability requirements relies on manual routines. However, I-1, I-6, I-8, and I-9 all claimed that all necessary information in the new projects is stored in the BIM server.

C. Business management

I-1 emphasized that, "Even though newer buildings have comprehensive BIM and older ones have employed simplified models, integrating the sub-models is currently unfeasible." When managing the building portfolio, the organization is struggling with the challenge of managing too many systems for localization, signaling the need for a transition to a unified Enterprise BIM solution (I-1, I-4 and I-6). I-6 noted that they have developed an enterprise architecture aimed at comprehensive Enterprise BIM management, but suitable software solutions have so far not been identified.

The interviews indicated a requirement for improved coordination of roles to establish a unified work plan, with I-4, I-6 and I-14 underscoring the need for internal organizational development and skills enhancement to navigate the demands of digitization. I-1 also mentioned the critical need for competencies to use building information effectively in the operational phase, which is currently reliant on individual efforts. Acknowledging the absence of a specific timeline, the Health Trust recognizes the necessity for a significant increase competence to leverage digitization strategies effectively.

I-14 from St. Olav's Hospital emphasized the importance of clearly defining metadata prior to system acquisition to preserve user trust. I-14 also emphasized the importance of clearly defining metadata prior to system acquisition to preserve user trust. According to I-14, "A uniform understanding, clear ownership, master data definition, and accountabilities for information updates are crucial for the success of Enterprise BIM." I-14 also expressed concerns about excessive autonomy across sections and departments, noting that "Continuous evaluations are lacking to determine if actions are efficient or cumbersome, such as extra databases that may introduce errors and ambiguities. There is a lack of accountability for coordination."

D. Project delivery and/or AM

The Toensberg project aimed to follow the workflow outlined in Figures 4 and 5, but deviations occurred due to manual product information documentation, as the Cobuilder (2023) Construction Product Data system did not meet expectations for using data templates with a unified data structure. I-9 noted, "Jotne's BIM server solution has functioned more as a project register during development, where the new buildings have been kept up to date in a digital twin solution based on updated IFC files." In addition, opinions within the organization differed as to whether IFC is suitable as master data in the Enterprise BIM solution, especially as highlighted by I-1.

In the last contract of the Toensberg project, negotiations were held to register all products and systems directly into the Jotne solution, supported by using GTIN, Serialized Global Trade Item Number (SGTIN), and Global Location Number (GLN) (Skoglund and Simonsen, 2019), and employing the Norwegian "Tverrfaglig Merkesystem" (TFM) for interdisciplinary identification. Despite using BIM to develop and link objects to the Jotne system for operational use, these negotiations also weakened the project's structure (Skoglund and Simonsen, 2019). However, project management (I-8 and I-9) and leading suppliers maintained close collaboration, facilitated by the contract form (I-11), which shared project outcomes.

The manual workload delayed product identification registration in the Jotne software, and complete as-built documentation was delivered long after construction had been completed. Nonetheless, the owner received a complete, updated, albeit visually as-built, model (I-11), criticized by I-7 for containing "much unnecessary information for the operational phase." Despite a strong focus on documenting all used products for future reference, it appears unclear from the interviews how this advantage can be used effectively in AM without aggregating as-built data in Project Information Models (PIM) into AIM adapted to end-user needs.

I-10 commented on the project's high BIM ambitions surpassing current market and system capabilities, resulting in numerous interim solutions and extensive manual documentation efforts. Additionally, interviews disclosed that neither the Toensberg project nor Vestfold Health Trust had adopted the ISO 19650 series, indicating a gap in standardized practices.

E. End-users

I-6 highlighted a significant organizational challenge, stating, "Around 99% of the focus among employees is on daily tasks as usual, and understanding complexity is difficult, and they prefer to avoid it." This suggests a resistance to complexity and a tendency for employees to follow personal agendas over a unified organizational approach. Consequently, I-6 emphasized the importance of prioritizing organizational development. Similarly, I-4 observed the immature use of BIM in operations and the low technological maturity of the operating organization, noting, "The Jotne software is not perceived as a holistic solution but as a solution to learn from in anticipation of something new." I-1 pointed out the weak interoperability between systems and the lack of integrated fire protection, underscoring systemic integration issues.

According to I-2, I-3, and I-4, the cleaning staff has long used a digital tool, Clean Pilot, which supports dynamic delivery processes. However, I-3 noted that the new project failed to provide essential information, leading to duplication of effort. The cleaning staff had to inspect new rooms and gather information independently. To streamline this process, they aim to integrate their informational needs into the overall information loop, highlighting the need to involve relevant end-users and consider their information requirements in new projects.

I-5, who successfully utilizes work orders linked to the Jotne solution for event-triggered updates, finds the BIM solution meets their needs but mentions some information that requires updating. This informant does not actively use GTIN and prefers system and product numbers for searching. I-9 introduced the potential for using SGTIN in asset identification, yet its integration into operational processes remains incomplete (BSI, 2020). Both I-1 and I-5 observe that GTIN, SGTIN, and GLN need to be more effectively tied to operational needs, indicating a lack of connection between digitization efforts and actual professional requirements.

In summary, interviews reveal significant gaps in information strategies, processes, and end-user engagement with IT solutions. These issues hinder the development and execution of an efficient and effective Asset Information Model (AIM) for AM, pointing to a broader need for organizational alignment and system integration, as well as a focus on operational effectiveness.

F. System model

To remedy the challenge of getting employees concerned with the complex whole, I-6 described how they largely use enterprise architecture to break it down into something close and manageable. I-6 explained that these build on various existing descriptions of how things should be done. Furthermore, there is a determination of the extent to which the Health Trust must align itself with these architectures and, if not, whether different suitable target architectures must be developed to describe the desired whole. I-6 believed that "the currently acquired BIM solution only covers part of this." At the same time, I-1, I-4, and I-6 explained that a contingency plan for handling various unforeseen events has yet to be included in their Enterprise BIM solution despite being desirable, according to the enterprise architecture.

The enterprise architect (I-13) said that the Central Norway Regional Health Authority is working with guidelines for a joint interregional procurement that includes all health regions in Norway. The service will support the entire value chain of assets and gradually develop the use of digital twins.

G. Technology

The Jotne BIM server is based on a Citrix virtual desktop infrastructure. The solution utilizes OpenBIM (IFC 4.2) as a BIM master data system and the Electronic Building Journal, for handling building systems and product and asset information. The interviews revealed that many technological solutions are minimally interconnected, resulting in unmanageable, siloed systems.

H. Detailed

Several informants highlighted the distribution of digital building information across too many applications, such as "Jotne BIM server," "Lydia property management," and "Clean Pilot cleaning," causing inefficiencies. I-6 noted that "the way the systems are built, and how the information is understood, must be more conceptual and value-oriented," pointing out the immaturity of integrating semantics with BIM in the operational phase. The absence of

a location the register in the Jotne Enterprise BIM solution necessitated the acquisition of a separate location register (I-6). I-6 detailed how this current separate location solution captures location-based triggering events related to patients, buildings, and equipment, further routing these incidents through administrative, facilities engineering, and clinical processes. Despite the lack of a direct connection to the BIM server, information was still extracted from it. I-6 emphasized the need for better communication between applications to create a cohesive system. They have implemented an integration solution that manages incidents via a process and task platform, allowing for the delegation of follow-up tasks to responsible roles for both planned and unplanned events. This solution enables rules in the location solution to be defined, such as algorithms that direct various triggers according to set rules, with role occupants viewing their tasks on mobile devices or PCs.

I-6 envisages future digital twins facilitating tailored follow-up actions for emerging situations, with routing connected to the specific realities each role manages, enhancing operational responsiveness and effectiveness.

I. Enterprise

I-6 highlighted: "Existing solutions can provide asset information to both external and internal end-users. However, information retrieval is limited to a predefined system, prohibiting free searches. For instance, searches may require system and product numbers. The strategy demands advanced use of asset information, incorporating the operational needs of the core business related to the assets."

Interviews and document analysis (I-1, I-4, I-6, Skoglund and Simonsen, 2019; Aarseth, 2020) have revealed deficiencies in the functionality of the Jotne Enterprise BIM solution. To coordinate events and utilize asset information organization-wide across all locations effectively and efficiently, it is preferred (I-6) to include a location system directly within the Enterprise BIM solution rather than separately. Furthermore, I-6 explained that a process and task platform is under development for integration, aiming to link value creation with information flows for cohesive information-driven work.

Simultaneously, I-1 and I-4 acknowledged that the competence in adopting technologies and systems is insufficient. Therefore, I-4 acknowledged that their competence in adopting technologies and systems needs to be improved. Furthermore, "users feel that the new BIM platform requires a completely different knowledge and understanding to be utilized in the various projects in the operating organization" (I-1). Therefore, many users experience the solutions as incomprehensible, unnecessarily complicated and discouraging, and refrain from entering information into the systems and, to a lesser extent, using them at all (I-1).

In summary, while the Tønsberg project and Vestfold Health Trust aspired to lead in Enterprise BIM implementation for AM, practical challenges such as system interoperability, user competence, and operational integration necessitated a re-evaluation of strategies and solutions. This case study reflects the broader industry's struggle to balance ambitious digital transformation goals with the practical realities of current technological and organizational capabilities.

5. DISCUSSION

The following discussion is divided into two parts. Based on the results, the first part discusses Vestfold Health Trust's position in establishing Enterprise BIM and its most conspicuous challenges. The second part discusses the way forward based on selected topics that are considered relevant for Enterprise BIM's further development.

5.1 The current state of implementing Enterprise BIM at Vestfold Health Trust

The structure of the developed extended Zachman Framework was helpful in organizing and categorizing the results, even though the framework mainly aims to define the different elements of the perspectives shown in Figure 2.

The results show that the Toensberg project has implemented IPD and an Enterprise BIM solution aimed at streamlining the handover workflow and enhancing AM outcomes. Through the IPD project, suppliers had to deliver more up-to-date information to the operational phase than they are normally used to, including comprehensive Radio Frequency Identification (RFID) or GTIN. For such a change to be possible, an agreement was concluded with Jotne (Jotne) to make the necessary adjustments so that the appointed parties involved could directly incorporate complete as-built product documentation into their Enterprise BIM solution (Aarseth, 2020). This pushed project participants and the construction industry to innovate and develop better solutions, especially in the areas of standardized objects and the provision of more complete information. In contrast, consistently, the high and partly unrealistic ambitions and the need for more clarification of expectations have reduced some of the desired positive effects of the measures (Skoglund and Simonsen, 2019). Due to the amount of manual work involved in finalizing the PIM, it was transferred very late to the Enterprise BIM solution and without optimal aggregation to AIM or sufficient clarification of end-user relevance. Although the suppliers gave very good feedback on the use of IPD, it still appears challenging to assess the project's utility value. The main reasons were that using an IPD contract was new for all participants, and the Jotne solution and GTIN were added after the original contract was concluded. In addition, the interviews show that the information needs of the end-users are not sufficiently taken into account when considered in the information requirements processes.

According to the interviews, the document analysis, and the preliminary project report, the Toensberg project was to implement continuous improvements. However, none have been implemented by the project organization (Skoglund and Simonsen, 2019). Instead of trying to make possible improvements, they tended to stop if something went wrong. As the new elements of the project were often difficult to implement, the participants often returned to traditional ways of working.

Several informants in the Health Trust organization noted that the current Enterprise BIM solution lacks sufficient operational functionality. The solution provides asset information access for both external and internal users, but its search and retrieval functions are confined to a predefined system, restricting free searches (I-6). Despite these limitations, the Health Trust chose the current solution to ensure access to all information in the future, pending better alternatives. However, this choice leads to additional costs related to the collection of information that has not been requested.

Thus, the surveys show several challenges and prerequisites for effectively using the Enterprise BIM approach. Due to the lack of a satisfactory and comprehensive enterprise solution, the Health Trust still has a conglomerate of digital solutions for end-users. It creates fertile ground for inefficient, unprofitable, silo-based systems (such as local spreadsheets) with low interoperability. At the same time, it prevents the information from being easily shared across disciplines and roles, as I-1, I-3, and I-14 also highlighted. To prevent users from relying on their own systems, they require IT solutions that offer simple and flexible access to building information. Furthermore, their new solutions must support formalized vulnerability management that identifies which critical assets may be affected during an emergency triggered by a failure in a building system.

Their current BIM strategy relies heavily on utilizing the IFC format and schema (see Figures 4 and 5). In contrast, IFC's limitations (Pauwels et al., 2017; El-Diraby, 2023) pose challenges for rational operational use, hinder end-users searching for flexible information and make subsequent reporting impossible.

The surveys underscore the urgent need for enhanced digital literacy within the organization. This is crucial to link projects effectively with new digital platforms and utilize data and information effectively. The study revealed gaps in the necessary understanding of BIM requirements for AM, interoperability, and use of technology in operations, a common issue confirmed by Kassem et al. (2015). Moreover, the organization overlooked standardization benefits, and none of the informants from Vestfold Health Trust were familiar with the ISO 19650 standard. These constraints collectively emphasize the pressing need for the organization to adjust to the evolving digital landscape.

5.2 Next steps to progress in developing Enterprise BIM

Enterprise BIM has been directly linked to only a few practical studies (Evjen et al., 2020a; Evjen et al., 2020b; Petersen et al., 2020; Petersen et al., 2023; Raviz and Petersen, 2021), and these studies have limited scope. They focus on a single hospital and demonstrate IFC-based prototype implementations that enhance stakeholder collaboration. These examples span a range of applications, from cleaning processes to equipment tracking and from indoor positioning to logistics optimization. However, given the potential impact on the field, the need for more comprehensive studies to address software challenges fully adapted to Enterprise BIM's needs is pressing.

The surveys have yet to find examples of comprehensive studies that show holistic and successful IT solutions for AM. The literature study shows a significant preponderance of conceptual but unimplemented approaches (Mayo and Issa, 2016), often having repeated and unresolved challenges such as a lack of interoperability, inadequate IT applications, unclear requirements, and a lack of involvement by various end-users. Kula and Ergen (2021) provide an overview of completed case studies for integrating AIM and AM. Nevertheless, only a few studies are related to long-term experiences and the use of developed systems in the operational phase, thus addressing the holistic challenge at full scale over time by showing real use in AM (Korpela et al., 2015).

As Vestfold Health Trust, many researchers have found that organizations need a cultural change and must develop digital competence and a suitable mindset (Korpela et al., 2015; Yalcinkaya et al., 2022; Kassem et al., 2015; Ashworth et al., 2016; Godager et al., 2022; Koch et al., 2019). Therefore, provision must be made for end-users to acquire the necessary BIM knowledge and to develop an attitude and approach to embracing the possible benefits of establishing useful asset information models to manage existing assets more sustainably and effectively (Ashworth et al., 2016; Kassem et al., 2015). Furthermore, a well-thought-out organizational development is thus an important condition for such value creation through BIM (Vass, 2015). This organizational development needs balanced interactions between people, processes, and technological systems to realize the models through AM business value (Munir et al., 2021; Bosch et al., 2015). The interviews showed that the focus at Vestfold Health Trust, as in the rest of the AECOO industry, has mainly been on new projects (Lindkvist, 2015; Munir et al., 2021) using contracted resources in almost all roles and functions. Therefore, more attention and resources should be allocated to address these highlighted challenges among appointing parties. Thus, increasing the focus and resources directed at these identified challenges for the parties involved can mitigate many industry issues.

ISO 19650's various information requirements and concepts enable standardized information processes (Godager et al., 2022; Godager and Mohn, 2022; Borrmann et al., 2018). The LOIN concept in ISO 19650 can ensure that different information requirements can be standardized, adapted to end-users' information needs, and included in AIM and further in Enterprise BIM (Godager et al., 2022). Using the LOIN concept also provides opportunities to build up a customized ontology that can be used for simple information searches and information management. However, to realize the potential of ISO 19650, it must be part of the business plan and must be communicated through the organization's information requirements (OIR) and asset information requirements (AIR). Unfortunately, this is often not the case today, even amongst clients using ISO 19650. Development of OIR and AIR (ISO, 2018b; ISO, 2020) can nonetheless significantly contribute to the success of Enterprise BIM (Godager et al., 2022). OIR includes strategic AM, strategic business operations, portfolio planning, regulatory (statutory) obligations, and policy design. Asset information requirements (AIR) define the information required to respond to OIR and the necessary information to reach the goal of AIM (Borrmann et al., 2018). AM decisions are taken at the strategic, tactical, or operational levels and can be reflected in the information requirements. In addition, to serve LOIN and associated information processes and be profitable and useful in value-chain considerations, a holistic Enterprise BIM solution requires the development of an integrated CDE ecosystem consisting of several CDE solutions (Godager et al., 2021) (see Figure 1).

Based on the case study and the literature studies, it is clear that IPD and BIM have several common fundamental cornerstones. Both concepts can support each other's implementation. Furthermore, IPD and BIM have the potential to be prominent collaborative concepts. They are, therefore, recommended for value creation, but existing studies have several different approaches and indicate weak scientific consistency (Karasu et al., 2023). However, the success of the implementation of IPD and BIM is strongly dependent on each other. IPD's full potential has yet to be achieved, even though many countries have used it for a long time (Walker and Rowlinson, 2019). IPD's underlying principle that the asset should deliver value in use fits very well with the intentions of Enterprise BIM as support for AM. In addition, the potential can be further increased by using ISO 19650's framework to develop the IPD contracts and the various BIM processes. ISO 19650 can, for example, support the contract by describing the purpose of information requirements (Çekin and Seyis, 2020), the level of information needed, and how and when it should be delivered so that the information is adapted to the end users' information needs in the operational phase.

"Boundary span" is a term that can describe or assess an organization's efforts to build a bridge of understanding between actors both within and outside it. In construction projects, the appointed parties are usually involved for a very short time and typically strive to understand the complexity of a larger organization. Furthermore, Dossick et al. (2023) demonstrate that, for projects within a larger building portfolio incorporating new technologies (IT infrastructure, IoT, and digital twins), employing temporal "boundary spanning" resources can enhance understanding. By emphasizing such bridging in complex projects, appointed parties can more easily supply the information the multi-phase organization needs. At the same time, ISO 19650, with its concepts and processes, is a bridge-builder in organizing information flow processes by describing why (purpose), where (information flow in CDEs), when, how, what, which (scope, quality, and details), and who will provide the information.

The case study revealed that BIM applications for AM need significant enhancements, as they currently rely on outdated technological solutions that are insufficient for addressing contemporary challenges. Accordingly, many building-management actors have invested wholeheartedly in using the IFC format as master data for a software application in the operational phase, built on the intended purpose of IFC to be extendable, allowing for the addition of new entity types and properties and ensuring interoperability and data consistency. This venture is proving challenging with respect to the efficient and profitable utilization of the information. Extending the schema requires a formal process and a deep technical understanding of IFC, which can be a barrier. Hartmann et al. (2017) show that business case-driven development resulted in uneven progress in domain-specific models and, along with redundant representation options, reduced the IFC standard's conceptual accuracy (Eastman et al., 2010).

Hartmann et al. (2017) point out the necessity of three important quality indicators for information models:

(1) Degree of semantic representation, (2) conceptual completeness, and (3) ease of implementation and raising queries for different purposes to build information that was not adequately addressed earlier.

At the same time, it is necessary to be aware that these three quality characteristics tend to conflict between the different purposes:

1. The degree of semantic representation refers to how well the BIM model can semantically represent the physical and functional characteristics of a building. A high degree of semantic representation means that the model can accurately convey the meanings and relationships of the building elements, which is crucial for interoperability and for different stakeholders to understand and collaborate with the model effectively. The challenge is ensuring that the semantic richness is manageable for the model's usability and implementation.
2. Conceptual completeness is about ensuring that the BIM standard encompasses all necessary concepts to describe building projects fully. It is a balance between achieving completeness, which can cover all stages of the building lifecycle, and the potential complexity that might make the model harder to use and implement. Understanding this trade-off can help prepare for the challenges and make informed decisions.
3. Ease of implementation and raising queries focus on how easily the BIM model can be integrated into existing workflows and systems and how easily information can be retrieved from it. The goal is to make BIM accessible to a wide range of users and software applications. However, the ease of implementation and querying often requires simplifying the model, which can be at odds with the goals of semantic representation and conceptual completeness.

IFC shows limited adaptability for rapid or improvised modifications, especially in dynamic contexts or when integrating non-traditional concepts outside the IFC framework (El-Diraby, 2023). Consequently, alternative approaches are needed to facilitate the seamless integration of building information across different data structures and to improve the analysis and the growing volume of unstructured data.

This article has highlighted the necessity for AM solutions that meet end-user's information needs. Therefore, asset owners must define the criteria to guide IT solution providers in delivering these functionalities. The approach to these end-user solutions must be based more on the performance of the assets and not only on the technical aspect function (Heaton et al., 2019). Furthermore, the classification and information structure should enable effective information searches, customized filtering, and exporting information based on the assets' functions (Heaton et al., 2019). Information needs and associated spin-off processes related to emergencies in critical assets triggered by

by failures in building systems must also be handled (Leite and Akinci, 2012). The development of such suitable end-user-based ontological models that provide a semantic description of end-users' information needs is rare in the AECOO industry, but research interest is increasing (Pauwels et al., 2017; Sadeghineko and Kumar, 2022). However, there is a need for more comprehensive measures that include further research and a focus on which technologies can increase the utilization of building information in AM.

At the same time, businesses need to assess which solutions will be able to provide the best overall result. Some studies show that the 3D-based approach only benefits a few end-users in the operational use phase (Yalcinkaya, 2017; Yalcinkaya and Singh, 2019). Much of the challenge is because design thinking dominates with customers and software suppliers. Therefore, the AECOO industry must emphasize what information is necessary and sufficient for each role in AM. Handling the information needs of these roles forms the basis for information requirements and CDE solutions and is supported by ISO 19650 (Godager et al., 2022; Godager and Mohn, 2022). LOIN-based information processes that must occur in CDE solutions can be supported by ISO 19650 (ISO, 2018b; Godager et al., 2022; Godager and Mohn, 2022). Alternatively, a 2D BIM-based, semantically rich user interface can be developed as well. Furthermore, detailed 3D BIM visualizations can be crafted to show only the relevant 3D geometry for specific contexts (Yalcinkaya et al., 2022).

Amidst various considerations, selecting a strategic and purpose-driven approach for IoT implementation is critical. Successfully integrating IoT demands merging traditional technology with information systems. Advanced IoT solutions promote the efficient linking of devices, systems, and applications within an interoperable framework. Digital twins, in serving as the virtual counterparts of physical devices and IoT systems, must be able to merge dynamic IoT data and static 2D and 3D model information, thus facilitating informed decision-making (Macchi et al., 2018). For digital twins to be effective, their purpose must be explicitly defined to tailor information requirements to their application.

However, because the AECOO industry is still in the early stages of adopting digital twins, it is necessary to define their content, standardize the processes, clarify the information requirements for the input, and define how they will be used in analyses and simulations. Due to supplier dependency, existing digital twin solutions have clear limitations (Halmetoja, 2022). That means that protocols must be standardized, allowing easier integration. In addition, the ISO 19650 framework can contribute to developing their OIR, AIR, and AIM, which could help establish digital twins in the operational phase (Godager et al., 2022; Robitaille et al., 2021; El-Din et al., 2022). Appropriate digital twins should be developed based on defined and customized end-user needs (Godager et al., 2022). For example, medical equipment and the tracking of movable equipment will be particularly important for hospitals.

Every major enterprise seems to need to use enterprise architecture to describe systems' complexity and relationships, with good involvement from the various end-users. When it comes to enterprise architecture, the Gartner Enterprise Architecture (EA) framework methodology is a strong contender. Its comprehensive approach is particularly effective for aligning IT strategy with strategic business goals. This alignment ensures proper execution and governance through frameworks and implementation plans, making it a strategic choice for many enterprises.

The Zachman Framework's main strength lies in its taxonomic completeness, a feature that reassures stakeholders about its ability to demonstrate the necessity of addressing multiple viewpoints in architecture. It ensures a holistic approach addressing a wide range of challenges and stakeholder needs (Sessions, 2007). It emphasizes the importance of involving a diverse group of stakeholders beyond architects and developers in the architectural development process, catering to a broader range of needs and perspectives. Godager et al. (2022) explain the extended Zachman Framework in more detail. Nevertheless, practical implementations require more detailed modeling, both within each perspective and for the business adopting the concept. Moreover, visualization-modeled relationships and needs can aid developers in creating improved IT solutions.

Implementing the Zachman Framework necessitates defining detailed processes, including a traceability matrix or metadata database cells, to maintain coherence among artifacts across all cells. This adds complexity and maintenance challenges, and the Zachman Framework needs guidance and process completeness, so moving from the generic to the specific could be challenging (Sessions, 2007). The weaknesses shown are considered to be less problematic from an organizational perspective. However, from an IT perspective, in order to develop the framework further in the next steps, the Zachman framework is still well suited to continue using another framework, such as TOGAF or Gartner, which better ensures the use of technology to drive business value.

At the same time, important questions remain about digital assets' information quality and completeness to support improved AM practices (Kim et al., 2020). To establish efficient, safe, and sustainable AM, stricter and more standardized requirements must be set for product descriptions and the tracking of products in building regulations (Hackitt, 2018), thus making it possible to standardize the AIMs to contain such information.

Overall, this study shows that the transition to the enterprise-based use of building information faces many challenges, especially related to the need for more knowledge and comprehensive information strategies. Increased emphasis on standardization around ISO 19650 is suggested as crucial for successful technological implementation, contract enhancement, and streamlining of processes, procedures, and IT solutions. The study proposes several measures to meet these challenges and emphasizes the need for further research to develop best practices and adapted IT solutions for end-users. Successful Enterprise BIM development depends strongly on the emergence of IT solutions based on end-users' specific information needs, where insights from different types of users have important roles in informing the design of the necessary ontologies and IT functionality.

6. CONCLUSION

This article, supported by literature studies, draws on a case study of Vestfold Health Trust, a significant player in the AECOO industry, to delve into the current position and challenges of implementing Enterprise BIM in asset management (Godager et al., 2022; Godager et al., 2021). The Health Trust, a keen adopter of BIM, set ambitious goals for Enterprise BIM utilization, which were realized through an IPD contract and the application of an Enterprise BIM IT solution. Although the Toensberg project has won international awards, the case study demonstrated deficiencies in information management, addressing the end-user's information needs and available IT solutions to achieve successful and holistic utilization in AM. The case study shows a strong need to strengthen the organization's digital competence to develop feasible improvement measures, improving understanding of the challenges and what is needed to solve them.

The selected case study, which included fifteen interviews, literature, and document studies, has laid the foundation for clarifying and discussing the status and the steps for progress in implementing Enterprise BIM for the AECOO industry. The study suggests that BIM applications for AM need enhancement, as they heavily rely on the digitization of analog processes and outdated technology that fails to address current AM challenges. For example, using the IFC format as master data for software applications in the operational phase shows limitations. Even though IFC is constantly evolving, the current version lacks the flexibility to accommodate rapidly changing contexts where multiple concepts or domains are linked together. At the same time, end-users are prevented from doing flexible information searches, making effective reporting impossible. Existing IT solutions lack formalized vulnerability management that identifies which critical assets may be affected during an emergency triggered by a failure in a building system and the specific information needs of the different roles involved. The surveys advocate reorienting the focus towards a greater involvement by end-users and their information needs based on the development of LOIN-based information requirements, as well as developing easily searchable IT solutions that include purpose-defined digital twins.

The article shows the industry's need for holistic digitization strategies. It presents new perspectives and numerous recommendations for fostering a comprehensive approach to strategies for managing building information across the value chain. It employs a previously developed Enterprise BIM framework, inspired by Zachman (2011), in a practical context to categorize and assess various aspects of Enterprise BIM. Furthermore, it emphasizes the importance of expanded knowledge in standards, standardization, and technologies to facilitate the development of necessary standardized processes.

The single case study has predominantly explored the experiences of carefully selected employees in various leadership positions. This selection may not capture the full range of the experiences and perspectives of the general user base, potentially limiting insights into the diverse challenges and successes in implementing Enterprise BIM. Such a focus might restrict the findings' applicability across the entire organization or to other entities. Additionally, as Enterprise BIM is a rapidly evolving field with limited literature, some findings may need to be updated with the advent of new technologies and methodologies.

Furthermore, research has yet to explore all the proposed measures at all deeply, so follow-up studies are needed. Examples of such focus areas are: (1) How to develop the necessary organizational knowledge and sufficient understanding of the interplay between people, technologies, and processes, supported by standardization to develop feasible Enterprise BIM-based strategies that successfully support AM (2); How to practically to develop standardized and purpose-driven information management based on the ISO 19650 series; (3) How can IPD and ISO 19650, in tandem with BIM, can make improvements for AM in new projects; (4) flexible, easily searchable IT solutions tailored to end users' information needs to ensure successful and profitable use; (5) ontology development based on end-users' information needs and associated semantic solutions that can process large amounts of data more efficiently How can IPD and ISO 19650, in tandem with BIM, can make improvements for AM in new projects; and (6) the creation of purpose-defined digital twins, which unite AIM and can handle a lot of IoT data. In addition, to support all categories of users of information related to the buildings, there is a need for future research that addresses access management challenges and information security.

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APPENDIX

Interview guide used as starting point for the semi-structured interviews at Vestfold Health Trust

Questions:

- What is your role at Vestfold Hospital?
- What is the strategy for effectively using digital building information?
- What types of agreements or contracts are used?
- How is BIM integrated into enterprise management (Enterprise BIM)?
- How is the necessity for information tailored to specific end-user roles during procurement?
- Which roles/end-users have been engaged in and considered a priority in the development process?
- How is the interoperability of data and information achieved?
- How is planning for unexpected events approached?
- What strategies govern the access to BIM information for the various user groups?
- What do you identify as key success factors for the organization's achievements?

Regarding the assessment and challenges:

- How do you evaluate the progress made thus far?
- What challenges are currently being faced?

Regarding standards and utilization:

- How will the implementation of GS1 and GTIN standards impact your role?
- What is your understanding of ISO 19650 and its relevance to your work?
- How are information management processes optimized for end-user utility?
- What classification standards are applied in your domain?
- How is information for operational use addressed in contracts and project execution?