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Enhancing Effective Information Management

Designing a Framework for Improved Implementation

Master's thesis in Design and Construction Project Management

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ABSTRACT

Effective information management is critical to the success of construction projects, yet the industry continues to face persistent challenges in this area. This study aims to investigate common challenges hindering efficient information management in construction projects, design a conceptual framework to address these challenges, and promote teamwork to facilitate effective information management throughout the project lifecycle. The research methodology involved a systematic literature review and interviews with key relevant stakeholders in the construction industry. The literature review encompassed academic papers, reports, and grey literature, ensuring a reliable and scholarly foundation for the investigation. The interviews involved professionals from construction companies, experts in information management, and relevant project stakeholders, providing a diverse representation of expertise within the industry. The study found that incomplete, inaccurate, or poorly defined information often leads to suboptimal decision-making, operational inefficiencies, and a reduction in the quality of facility operation and maintenance. The proposed framework is designed to establish a structured approach to information management in the construction industry, aligning closely with the real-world needs and challenges identified during the interview process. It is based on the principles and guidelines outlined in the ISO 19650 standard and can potentially provide practical solutions and recommended tools to facilitate the seamless implementation of the standard. The framework promotes teamwork and collaboration among stakeholders, ensuring that information is communicated transparently and exchanged with the appropriate individuals at the right time. By addressing the persistent challenges in information management, the proposed framework can help construction projects achieve success and deliver value to customers.

Key words: effective information management; information management challenges; conceptual framework; ISO 19650 standard; implementation; communication.

Förbättra Effektiv Informationshantering

Designa en Ram för Förbättrad Implementering

Masteruppsats i Design och Projektledning för Byggprojekt

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SAMMANFATTNING

Effektiv informationshantering är avgörande för framgången med byggprojekt, men branschen står fortfarande inför ihållande utmaningar inom detta område. Denna studie syftar till att undersöka vanliga hinder som försvårar effektiv informationshantering i byggprojekt, utforma en konceptuell ram för att hantera dessa utmaningar och främja teamwork för att underlätta effektiv informationshantering genom hela projektets livscykel. Forskningsmetodologin inkluderade en systematisk litteraturgenomgång och intervjuer med nyckelintressenter inom byggbranschen. Litteraturgenomgången omfattade akademiska artiklar, rapporter och grå litteratur och säkerställde en pålitlig och vetenskaplig grund för undersökningen. Intervjuerna involverade yrkesverksamma från byggföretag, experter inom informationshantering och relevanta intressenter i projektet, vilket gav en mångfaldig representation av expertis inom branschen. Studien visade att ofullständig, felaktig eller dåligt definierad information ofta leder till suboptimalt beslutsfattande, operationella ineffektiviteter och en minskning av kvaliteten på anläggningsdrift och underhåll. Den föreslagna ramen är utformad för att etablera ett strukturerat tillvägagångssätt för informationshantering inom byggbranschen och är nära anpassad till de verkliga behoven och utmaningarna som identifierades under intervjuerna. Den bygger på principer och riktlinjer som anges i ISO 19650-standarden och kan potentiellt erbjuda praktiska lösningar och rekommenderade verktyg för att underlätta den sömlösa implementeringen av standarden. Ramen främjar teamwork och samarbete bland intressenter, säkerställer att information kommuniceras transparent och utbyts med rätt personer vid rätt tidpunkt. Genom att adressera de ihållande utmaningarna inom informationshantering kan den föreslagna ramen hjälpa byggprojekt att uppnå framgång och leverera värde till kunder.

Nyckelord: Effektiv informationshantering; utmaningar inom informationshantering; konceptuell ram, ISO 19650-standard; implementering, kommunikation.

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Preface

As we embark on the journey of presenting our Master's thesis in Design and Construction Project Management, we find ourselves filled with gratitude and a profound sense of accomplishment. This endeavour would not have been possible without the unwavering support and guidance of numerous individuals who have played pivotal roles in shaping our academic and personal growth.

First and foremost, we extend our heartfelt appreciation to our esteemed supervisor, Dimosthenis Kifokeris, whose expertise, mentorship, and encouragement have been invaluable throughout this research journey. His insightful feedback, constructive criticism, and unwavering support have propelled us forward, challenging us to strive for excellence in our work. Furthermore, we would like to express our deepest gratitude to our husbands, families, and friends for their unwavering support, patience, and understanding during this demanding period of academic pursuit.

Their endless encouragement, love, and belief in our capabilities have been our source of strength and motivation, inspiring us to persevere through challenges and setbacks. The culmination of this thesis represents our collective effort to address the persistent challenges facing the construction industry, particularly in the realm of information management. As highlighted in the conclusion of our thesis, the escalating costs, conflicts among stakeholders, and customer dissatisfaction underscore the urgent need for effective information management practices within the construction sector. Through a research methodology comprising comprehensive literature review and insightful interviews with key stakeholders, we sought to unravel the intricacies of information management challenges and devise a robust framework to address them.

We fervently hope that our thesis contributes to the ongoing discourse on improving information management practices in the construction industry, ultimately fostering collaboration, transparency, and efficiency across project lifecycles. It is our sincere belief that the insights gleaned from our research will serve as a catalyst for positive change, empowering stakeholders to navigate the complexities of construction projects with greater confidence and success.

MARWAH FARIS

ENAYA TOULIMAT

List of Abbreviations

AECO	Architecture, Engineering, Construction, and operation
AIM	Asset Information Model
AIR	Asset Information Requirements
BCF	BIM Collaboration Format
BEP	BIM execution plan
BIM	Building Information Modelling
BSI	British Standards Institution
CDE	Common data environment
COBie	Construction Operation Building Information Exchange
EIR	Exchange Information Requirements (
FM	facility management
IAI	International Alliance for Interoperability
IFC	Industry Foundation Classes
IM	Information management
LOIN	Level of Information Needed
MVD	Model View Definitions
OIR	Organizational information requirements
PIM	The Project Information Model
PIR	Project Information Requirements

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1 Chapter One: Introduction

1.1 Introduction

In the realm of effective information management across diverse project phases, several challenges could potentially impacting project success (Mayo and Issa, 2014). One of the most prominent issues revolves around the need for transparent and open communication among project stakeholders, a key factor in preventing conflicts, maintaining project timelines, and controlling unexpected cost escalations. This issue, which results from a lack of knowledge about roles, responsibilities, and information requirements, is a frequent roadblock for construction projects, Moreover, the absence of a centralized and well-structured platform complicates the tracking, documentation, and management of project requirements, further exacerbating the challenge of maintaining a systematic approach to information management (Said et al., 2022). Additionally, construction projects struggle with fragmentation in information management across phases, stakeholders, and individual project instances, each distinct phase, such as initiation, design, construction, operation, and maintenance, presents formal information handovers, often resulting in data loss during these transitions, the involvement of various stakeholder groups, each with its own set of tools and methodologies, adds another layer of complexity to this fragmentation (Adriaanse, 2014).

The challenges in information management extend beyond construction projects, affecting facility management as well. Here, the quality of the information takes centre stage. Incomplete, inaccurate, or vaguely defined information can lead to suboptimal decision-making, operational inefficiencies, increased costs, and a decline in overall facility quality (Leygonie, 2022). Simultaneously, information overload creates significant hurdles for facility operators, making it difficult to access crucial data, overwhelming databases, and diminishing operational efficiency (Leygonie, 2022). The prevalent use of static documents and the limited adoption of Building Information Modelling (BIM) during the operation and maintenance phases present challenges for effective information management in facility management, moreover the barriers to the industry-wide embrace of BIM in facility management include contractual constraints, interoperability issues, and high upfront costs (ABAB, 2018; Durdyev et al., 2021).

In light of these challenges, this study sets out to explore and identify common obstacles in information management across construction projects and various stakeholders. Through a systematic literature review and empirical work involving interviews, the study aims to create a robust framework that can rectify misunderstandings, promote effective teamwork, and ultimately enhance project outcomes.

1.2 Problem Statement

The construction industry is continually facing a multitude of challenges, including resource and time waste, escalating costs, conflicts among stakeholders, and customer dissatisfaction. These challenges not only impede the industry's growth but also have broader implications for society, such as increased project costs and delays in infrastructure development. A fundamental contributor to these issues is the ineffective management of information throughout the project lifecycle. Incomplete, inaccurate, or poorly defined information often leads to suboptimal decision-making, operational inefficiencies, and a reduction in the quality of facility operation and maintenance. Information overload further compounds these problems, undermining overall productivity and project success (Adekunle, 2022). Based on that, addressing these challenges and improving information management practices in the construction sector is not only essential for the industry's sustainability by optimizing resource allocation by preventing unnecessary waste in time, cost, and effort but also for ensuring the timely delivery of infrastructure and facilities that meet society's needs and expectations. This study seeks to identify, analyse, and propose solutions to the issues surrounding information management in construction while creating a framework with the overarching goal of enhancing project outcomes, supporting successful facility operations, and reducing life cycle expenses.

1.3 Objectives of The Study

1. Investigate common challenges in information management: Through a systematic literature review and interviews, this research aims to identify and analyze the common challenges that hinder efficient information management in construction projects across various stakeholders.

2. Design an effective framework for information management: Building upon the collected data, a conceptual framework will be designed. This framework provides a structured approach to addressing challenges and improving information management practices across various stakeholders. It can serve as a guiding structure for how information is managed throughout the project.

1.4 Scope of Study

This research aims to address the common challenges related to information management throughout all project phases. Given the extensive scope of potential challenges across the project life cycle, the study acknowledges limitations related to time and resources. Therefore, the investigation will prioritize the identification and analysis of the most common issues encountered in information management practices within the construction industry. Furthermore, this study is limited to companies and experts within the construction sector in Sweden. While the challenges faced by construction projects may have universal aspects, this research will provide insights specific to the Swedish context. The choice of a specific geographic region allows for in-depth exploration while recognizing the potential variations that may exist in different international contexts.

The study will include interviews with a selected number of construction companies and experts in Sweden. Although this sample size may not encompass the entire industry, it will provide valuable insights into the prevailing challenges and potential solutions within the Swedish construction sector. It is important to note that this research may not comprehensively cover all challenges or provide a fully international perspective, and thus, further investigations on a broader scale may be warranted for future studies.

1.5 Outline

This thesis includes an exploration of the challenges related to information management in construction projects and provides a suitable conceptual framework as a solution. The document is structured as follows:

- CH1 Introduction: Provides the background, problem statement, objectives, and scope of the study.
- CH2 Literature Review: Explores existing research on information management in construction, challenges, and relevant theories.
- CH3 Methodology: Describes the research design, data collection, and analysis methods employed.
- CH4 Results and discussion: Interprets findings, then proposes a framework as a guideline to avoid identifying the addressed challenges related to information management
- CH 5 Conclusion: summarizes key findings and their implications, discusses limitations, and suggests future research directions.
- References
- Appendix

2 Chapter Two: Literature Review

2.1 Introduction to Information Management in Construction

2.1.1 Role of Information Management in Construction Projects

Within the context of the construction industry, effective information management plays a pivotal role in facilitating productive collaborative interactions (Ness, 2017). According to Ness (2017) It entails ensuring the accuracy and effective distribution of data produced by the construction team to various stakeholders, including contractors and builders. Given the inherent volatility and unpredictability in the construction sector, construction managers heavily rely on information that is both accurate and dependable, employing information management strategies as a means of contingency planning (Van de Ven, 2013). (Redpath, 2013) stated that improved information management holds the promise of offering deeper insights into inventory-related challenges and aiding in the reduction and mitigation of uncertainty, although these potential benefits remain underexplored, and since information is integral to decision-making processes, the quality of information exchanged directly impacts the perception of organizational success, additionally, the enhanced information flows made possible by digital technologies may have an impact on construction managers' assessments of how such agreements will affect their firms' operations. According to Pan and Zhang (2021) cooperative deployment of digital solutions enhances control and administration of the substantial volume of information generated during construction processes, thereby augmenting public perception of the advantages associated with construction information management, particularly in terms of lowering uncertainty and transaction costs.

Adekunle's (2022) study aimed to identify the benefits of construction information management in the digital age. Their findings revealed several significant benefits associated with effective information management. Initially, the promotion of productive collaborative relationships within the construction industry is significantly influenced by efficient information management. Also, accuracy and efficient sharing of information with stakeholders, including contractors and builders, serve as reliable indicators of proficient information management. Additionally, it was found that competent information management offers valuable insights into inventory-related challenges and contributes to the reduction and management of uncertainty. This, in turn, leads to improved decision-making processes and enhanced project outcomes. Moreover, efficient information management correlates with heightened efficiency and productivity in construction projects, facilitating better communication and coordination among the various stakeholders involved. Strong information management also supports improved risk management and mitigation, quality control, and assurance, as well as project cost control and management. These findings by Adenkunle (2022) underscore the critical role of systematic information management in the construction industry, highlighting its potential to positively impact various facets of construction projects.

According to the UK BIM Framework, Guidance Part 1 (2021), information management encompasses various tasks, including defining information needs, creating, verifying, and delivering data this practice applies universally to all types of information, collectively termed an 'information model,' encompassing structured and unstructured data, spanning geometric, alphanumeric, and documentation elements. Recently the importance of effective information management has grown significantly, leading to improved project outcomes.UK BIM Framework, Guidance Part 1 (2021). UK BIM Framework also refers that these benefits include enhanced coordination, improved data quality, timely information delivery, reduced costs, well-informed decision-making, and precise record-keeping, and by achieving these advantages necessitates collaborative efforts and systematic information management throughout an asset's lifecycle, contributing to the betterment of our built environment.

The shift toward digital work methods underscores the necessity for robust information management practices, to unlock efficiencies and enable efficient information use and reuse, it is imperative to consistently and systematically specify, produce, review, approve, and exchange information (Abdul Rahman, 2020). Abdul Rahman (2020) also stated that technology's potential benefits rely on these structured approaches, conversely, poor procurement and management of digitally delivered information can pose greater risks than their analogy counterparts, including issues related to access control, distribution, and security breaches thus recognizing 'information as an asset' holds vital importance within the industry, information-driven decisions have an impact on outcomes at both the business and project levels Therefore, information management must be ingrained and held in the same regard as design, project management, and asset management, as it plays an equally critical role in achieving successful construction projects in the digital age (UK BIM Framework, Guidance Part 1, 2021).

2.2 Overview of Information Management Challenges

2.2.1 Resistance to Adopting a New approach

In his study (Ahmed, 2018) mentioned the significant impact of social and habitual resistance to change on the implementation of BIM in the construction industry, his study highlighted the resistance to change is a natural factor within every living being and that uncertainty about change tends to make stakeholders reluctant to transition from traditional methods to more innovative approaches. Ahmed (2018) study emphasizes that stakeholders in construction projects are accustomed to and proficient in traditional methods, making it challenging to replace these methods with BIM and this resistance poses a substantial barrier to the adoption of BIM technology in the construction industry.

Understanding the resistance to BIM implementation involves recognizing critical barriers within the construction industry. These barriers encompass limited awareness, inadequate training, reluctance to alter traditional work approaches, and challenges related to software compatibility, notably user perception of BIM significantly influences its acceptance and effective utilization (Howard, 2017). Recognizing the benefits of BIM can induce changes in traditional work methods, potentially reducing resistance as more clients acknowledge its advantages (Marley, 2015).

Furthermore, as mentioned by Lindbald and Vass (2015) the integration of BIM induces changes across organizational function which include BIM management system alterations, including defining BIM use levels, introducing mentorship, establishing new role descriptions like BIM coordinators, and adhering to industry standards, measuring BIM's impact involves evaluating organizational knowledge and attitudes toward BIM, often using key performance indicators (KPIs). Howard (2017) stated that enhancing BIM-related skills necessitates competencies and framework agreements for BIM coordinators and managers, alongside specialized BIM training courses.

Additionally, the adoption of new industry standards represents a potential paradigm shift, yet it faces significant hurdles, including stakeholder apprehension regarding costs outweighing benefits, as a result, cautious adoption strategies predominate, driven by a wait-and-see attitude, particularly among private companies (Sadrinooshabadi et al., 2021). Sadrinooshabadi (2021) study refer that Implementing new systems demands substantial time and effort, necessitating a well-structured educational program for all involved parties, his study include a practical example presented by underscores the need for effective education and awareness in embracing innovative systems, such as CoClass (which is categorization framework employed in building information Modelling (BIM) and facility management (FM) for the purpose of organizing and classifying elements within a building or facility), in BIM and facility management. Sadrinooshabadi results showed that when this information is transferred to the facility management team, they often struggle to grasp the significance of its classification and the associated advantages and unfortunately, due to a lack of understanding, they may dismiss it, viewing it as a time-consuming and labour-intensive task so they are often unaware of the substantial role this system plays in streamlining information management and distinguishing between various elements. Sadrinooshabadi also stated that reluctance to embrace the system is primarily rooted in the need for effective education and awareness, and addressing individual resistance to change, deeply rooted in human characteristics like perceptions, personalities, and individual needs, necessitates effective communication between management and employees.

2.2.2 Misunderstandings and Conflicts Due to Unclear Requirements

Establishing transparent and open lines of communication among all project stakeholders is a crucial factor that significantly impacts the success of engineering projects. This should be initiated right from the project's inception, as emphasized by Mayo and Issa (2014). Mayo and Issa (2014) underscored the importance of ensuring that every party involved in a project possesses a well-defined comprehension of their roles and responsibilities; that's why it is crucial for each party to be cognizant of the specific information or requirements essential to their tasks, as well as the pertinent details that necessitate communication or exchange with the appropriate individuals, all in a timely manner. This challenge looms large within today's construction industry, resulting in conflicts among project stakeholders, disruptions in project timelines, and unanticipated increases in project costs (Mayo and Issa, 2014).Another significant hindrance in asset information management is that the appointing parties may lack the necessary knowledge to articulate their needs, or they may simply be unaware of their specific requirements (Sadrinooshabadi et al., 2021).

Durdyev et al. (2021) emphasize the significance of well-defined information requirements, noting that the data presented during project closeout may not meet the actual needs of facility managers and operators without clear specifications. This misalignment between provided data and operational necessities can result in a diminished utility of the delivered information. The authors advocate for addressing this challenge by establishing clear and comprehensive requirement definitions early in the project. This proactive approach ensures that the data generated and provided throughout the project lifecycle closely aligns with the genuine requirements for effective facility management (Durdyev et al., 2021).

2.2.3 The lack of Common Work Environments

Ineffective information management poses significant challenges for users, requiring them to invest precious time in the often-futile search for data that can be incomplete, irrelevant, or missing altogether; this situation can be attributed to organizations overlooking the importance of regular information updates and oversight (Said et al., 2022).

Moreover, said (2022) stated that the fragmented distribution of data across various systems, each with its own specific function, and the lack of coordination among project stakeholders further exacerbate the problems in managing information consistently within facility operations; as a result, these inconsistencies give rise to unnecessary costs and operational inefficiencies. Said (2022) also mentioned that the absence of a centralized, well-structured platform can also complicate the process of tracking, documenting, and effectively managing requirements; this deficiency can lead to difficulties in maintaining a systematic approach to information management. Rahman’s and Gamil's (2019) study highlight the critical significance of effective communication as a foundational competence for the triumph of construction projects, nonetheless, achieving this level of effective communication remains a formidable task within the construction sector, primarily due to the industry's intrinsic traits. The construction field is inherently characterized by fragmentation and dynamism, featuring numerous stakeholders ranging from clients and consultants to contractors and regulatory bodies (Rahman & Gamil, 2019). According to Rahman’s and Gamil's (2019) this intricate web of involvement frequently leads to communication obstacles, ultimately manifesting in situations where information exchange is less than optimal and inefficient.

2.2.4 Interoperability Challenges and Inefficient Information Exchange

Adrians (2014) highlights that the management of information in construction projects frequently confronts difficulties due to fragmentation across diverse project phases, stakeholders, and unique project situations. Distinct phases such as initiation, design, construction, and operation and maintenance exhibit clear demarcations with formal information handovers, often resulting in information loss during transition; various groups of stakeholders bring their own set of tools and methodologies, exacerbating this fragmentation (Adriaanse, 2014).

In the different phases of a construction project, a substantial volume of data is generated from various sources and disciplines, leading to a complex environment for the exchange and transfer of information, as indicated by Adriaanse (2014). This data follows a convoluted network involving exchanges, transfers, and publications, utilizing a diverse range of software applications and methodologies (Adriaanse, 2014). Svensson and Friberg (2019) specify some of the challenges, such as the lack of standardized information structures to facilitate information exchange between different actors during the asset life cycle. They also assert that it is highly time-consuming and challenging to bring different types of data together, which distinctively reveals the communication issue. Unfortunately, existing owner standards often lack comprehensive directives for achieving these objectives (Durdyev et al., 2021).

As highlighted by Said (2022), a significant challenge in this context stems from the widespread use of multiple software applications employing proprietary file formats, the heavy dependence on closed file formats poses a substantial obstacle to the smooth exchange of data, were certain files are formatted in a manner that restricts their accessibility and interpretation to specific software applications. Said (2022) pointed out that it is impractical and unfeasible to anticipate employees mastering all these programs to proficiently handle diverse file types, depending solely on a single software program for all project phases can result in challenges. Therefore, Said (2022) stated that the use of multiple software applications with proprietary file formats poses a significant hindrance, emphasizing the urgent requirement for enhanced data management and sharing solutions ensuring accessibility and comprehensibility of information throughout the project's life cycle; neglecting to address the structure of this information could lead to an absence of interoperability.

(Grilo and Jardim, 2010) define interoperability as the capability of diverse systems or components to exchange information and effectively utilize the shared data. Grilo and Jardim study emphasizes the necessity for each application's data structure to align with a shared data model to enable mutual understanding of exchanged data, and a crucial aspect is having an open and accessible shared data model, allowing any application to seamlessly integrate and function with others that have undergone a similar adaptation.

As outlined by Grilo and Jardim-Goncalves (2010), the advantage of interoperability lies in its potential to save both time and resources that would otherwise be expended on individually integrating each application for compatibility.

As emphasized by Redmond (2012), a significant challenge in the field of BIM arises from the limitations in various BIM applications' ability to communicate effectively with each other. This challenge has prompted the search for practical solutions, given that one of the core attributes of BIM is its capacity to facilitate the seamless exchange of synchronized information among diverse software applications (Redmond, 2012).

2.2.5 Inefficient BIM Usage in the Operations and Maintenance Phase

BIM has garnered considerable attention in the Architecture, Engineering, Construction, and operation (AECO) sectors, particularly during new construction projects, however, realizing the full potential of BIM extends beyond project delivery and requires proactive planning for the operational phase. Unfortunately, in many BIM projects, the focus on data collection and management primarily occurs during the design and construction phases, with the operational phase often receiving insufficient attention (Pinti, 2022). In the realm of utilizing BIM during the operations and maintenance phases, a significant challenge, as noted by Heaton (2019) and Ghosh (2015), is the absence of well-defined information requirements for facility owners. Frequently, owners encounter difficulties in articulating deliverables or specifying essential information due to a lack of familiarity with BIM data models (Heaton et al., 2019; Ghosh, 2015). This absence of precise information requirements, especially when not included in contractual documents, leads to delivered models lacking crucial information for facility operation and maintenance (Heaton et al., 2019; Ghosh, 2015). As emphasized by Heaton (2019) and Ghosh (2015), the precision and pertinence of information conveyed to owners play a pivotal role in the successful application of BIM in facility management. Regrettably, current handover procedures encounter challenges, including delivery delays, incomplete documentation, and inconsistencies in the information provided, this often leaves owners with insufficient details about the handed-over equipment and systems, necessitating manual data entry into facility management systems (Heaton, 2019; Ghosh, 2015).

Addressing additional challenges, as highlighted in Mayo and Issa's (2016) study, data overload emerges as a significant concern. Although information is crucial for efficient facility management, an abundance of unnecessary data can become overwhelming and counterproductive.

In the study conducted by Durdyev (2021), they underscore the importance of distinguishing between valuable information and unused data, for example facilities management staff have a primary need for non-geometric information, and it is crucial to establish clear deliverable requirements for gathering information with a specific purpose. Effective facility management hinges on the adept handling of data volume and structure, Durdyev (2021) study emphasizes that data overload can impede facility operators, posing challenges in extracting essential information and consequently diminishing operational efficiency.

To comprehensively tackle these challenges, Alnaggar and Pitt (2019) advocate for the establishment of a cohesive strategy that ensures the effective utilization of (BIM) throughout the entire lifecycle of a facility, this strategy should encompass well-defined information requirements, structured handover procedures, and effective data management practices. Alnaggar and Pitt (2019) study underscores the importance of the early involvement of facility management professionals, enhancing awareness of BIM benefits in the FM sector, and addressing issues related to software interoperability and process efficiency, Ultimately, this approach aims to facilitate a smooth transition from the construction phase to operations and maintenance, thereby enhancing the efficiency of facility management processes.

2.3 Solutions for Information Management Challenges

2.3.1 Resistance in Adopting New Industry Standards

To successfully implement a new technology and achieve the benefits of standardization while increasing awareness of information management, organizations must address resistance to change where the resistance to change is common when introducing new technology. (Singh, 2015). In his study Singh (2015) suggested practical strategies for addressing this resistance include: Actively engaging employees in the change process and encouraging their participation and input in decision-making; providing training and support; and facilitating effective communication to help employees understand the purpose of the transformation and reduce uncertainty.

(Lindblad and Vass, 2015) In a case study based in Sweden, an exploration into the initiation of BIM implementation within a large public client's organization was conducted, this study delineated the shifts engendered by BIM implementation into four primary areas. Firstly, BIM Management Systems experienced transformation encompassing the definition of the lowest level of BIM utilization within the organization, the provision of BIM mentoring, the introduction of novel role descriptions such as BIM coordinators and BIM managers, and the adoption of industry standards; Secondly, BIM measurements became pivotal, involving an investigation into the organization's level of knowledge regarding BIM, assessment of attitudes towards BIM, and the utilization of measurements such as key performance indicators (KPIs) to gauge BIM efficacy. Thirdly, BIM skills were evaluated, focusing on competencies and framework agreements tailored for BIM coordinators and BIM managers; Lastly, BIM education was considered, taking into account specialized BIM training courses aimed at enhancing skills and knowledge pertinent to BIM within the organization.

Change models are frameworks or theories that provide structured approaches for understanding, managing, and implementing change within organizations; they offer guidance on how to navigate the complexities of change and facilitate successful transitions; one such model is the ADKAR change model (Ali and Nazim, 2021). ADKAR model was initially discovered by Hiatt (2006), it is a change management framework that focuses on the people's side of change within organizations; the model's five building blocks (Awareness, Desire, Knowledge, Ability, and Reinforcement) provide a structured approach to addressing the individual transitions that occur during technology implementation. By focusing on each of these elements, organizations can better understand and address the needs and concerns of individuals, ultimately facilitating successful technology adoption and implementation, the model provide a structured approach to understanding and addressing the individual transitions that occur during organizational change initiatives (Hiatt, 2006). (Ali and Nazim, 2021) study found that the ADKAR model it has a significant impact on technology acceptance, indicating that managing the people side of change is crucial for successful technology adoption, it emphasizes the importance of addressing the needs and concerns of individuals as they navigate through the process of change, ultimately aiming to facilitate successful change adoption and implementation. Table 2.1 presents the definition of the ADKAR model acronym.

Table 2.1 Definition for the ADKAR model acronym.

ADKAR PRINCIPLE	**DEFINITION**
Awareness	Business reason for change
Desire	Desire to engage with the change
Knowledge	Having the information to change
Ability	Action planning/ implementing change
Reinforcement	Ensuring the change sticks

MacLoughlin (2019) suggested a conceptual framework for using the ADKAR model of change to enhance BIM implementation in construction projects through two main phases of determinants for a successful change management process. The author argues that the ADKAR model can contribute to the successful adoption of BIM in the construction sector by enhancing all five dimensions of ADKAR for lasting change.

MacLoughlin's (2019) integrated conceptual framework of change management is shown in Figure 2.1.

Figure 2.1 BIM adoption aligning change management method

Errida and Lotfi (2021) discuss various factors that can affect change management success, including leadership, political support, and sponsorship; they also mention the importance of a structured approach to change and continuous improvement. Political support involves backing from external parties like government agencies, rules and regulation bodies, or other influential groups for an organization, this support plays a crucial role in making organizational changes successful by offering essential resources, credibility, and impetus to overcome resistance and execute the changes effectively. Errida and Lotfi (2021) discuss the importance of sponsorship in ensuring successful change initiatives; sponsorship refers to the role that leaders play in aligning stakeholders to support and own the change and effective sponsorship involves engaging stakeholders, communicating the vision and benefits of the change, and providing the necessary resources and support to ensure successful implementation. In their 2021 study, Errida and Lotfi (2021) emphasized the pivotal role of effective sponsorship in success within change management benchmarking studies, highlighting the significance of external consultants and experts in enhancing change efforts, particularly in areas where organizational proficiency or resources are lacking, involving training, coaching, consulting services, and the use of specialized tools and technologies. Nevertheless, Errida and Lotfi (2021) caution that employing external support should be done thoughtfully, organizations must exercise prudence in selecting consultants and experts possessing the essential skills and experience tailored to meet the organization's specific needs. Furthermore, the researchers underscore the importance of cultivating in-house capabilities for change management. This involves enhancing the skills and knowledge of internal personnel and fostering a culture of ongoing improvement and learning (Errida and Lotfi, 2021).

2.3.2 Misunderstandings Due to Unclear Requirements (The Lack of Transparency, Coordination, and Alignment

Clear rules and standards play a major role in ensuring that all project stakeholders have a common understanding of their responsibilities and expectations while using BIM (Ashworth, 2023). ISO 19650-1: (2018) serves as a foundation for these rules and standards, offering guidance that promotes effective collaboration among various parties and providing unambiguous guidelines that everyone can adhere to (Ashworth, 2023). Ashworth (2023) emphasizes the importance of collectively defining information requirements in collaboration with all project stakeholders and maintaining an ongoing process of review and updates throughout the project's entire life cycle.

In accordance with Sanhudo et al. (2018), the effective implementation of BIM necessitates that appointing parties, as specified in ISO 19650-1: (2018), enforce the adoption of current standards for specifying requirements. These standards, often manifested as contractual or legal obligations, ensure that all involved parties, including the design team, suppliers, and contractors, adhere to consistent guidelines and are assessed using identical criteria. As emphasized by Sanhudo et al. (2018), the preparation of proposals by appointing parties should involve the creation of standardized information, this approach fosters clear communication among stakeholders, contributes to maintaining high project quality, and prevents misunderstandings.

ISO 19650 is a series of international standards that offer a comprehensive framework of guidelines and requirements for effectively managing information throughout the entire life cycle of built assets, primarily through the utilization of BIM (Ashworth, 2023). Its evolution is intricately linked to the development and maturation of BIM practices. ISO 19650 comprises various parts, each dedicated to specific facets of information management within the built environment (UK BIM Framework, Guidance, 2020). ISO 19650 emerged in response to the global demand for standardized BIM practices, before its introduction, various countries operated with their own BIM standards (Ajayi, 2021). In recognition of the necessity for global BIM standardization, international collaboration took root, organizations such as the International Alliance for Interoperability (IAI), later known as Building SMART International, played pivotal roles in advancing interoperability and standardization in the construction sector (Ajayi, 2021). In the United Kingdom, the development of BIM standards culminated in the release of PAS 1192 (Publicly Available Specification) by the British Standards Institution (BSI), ISO 19650, by building upon the foundational elements of PAS 1192 and diverse national standards, has crafted a unified framework for the efficient management of digital information within the construction industry (Ajayi et al., 2021). Like many other ISO standards, ISO 19650 undergoes periodic updates to remain aligned with dynamic industry trends and evolving technology (Ashworth, 2023). In Europe, it has been adopted in several contexts and is progressively supplanting numerous local standards that were previously crafted by individual countries (Ashworth, 2023).

Based on the insights provided by Eriksson (2020), the adoption of international standards like ISO 19650 as a standard for building information management in Sweden emerges as a highly beneficial choice. Eriksson (2020) study underlines the increasing prevalence of 3D representations of buildings and their integration into city planning and decision-making processes. Given this trend, aligning with a globally recognized standard like ISO 19650 becomes essential. The study encourages the selection of international standards due to their well-established nature and higher likelihood of widespread software tool implementation (Eriksson,2020). Furthermore, the structured approach and classification system of ISO 19650, as outlined by Eriksson (2020), align with the study's recommendation to incorporate a classification system into the national standard. This alignment facilitates more effective information management by promoting uniformity, interoperability, and collaborative efficiency, not only within Sweden but also on an international scale (Eriksson, 2020).

In accordance with Eriksson's (2020) findings, the utilization of ISO 19650 plays a pivotal role in achieving the study's objectives, this includes defining requirements, adopting a standardized approach, generating consistent test data, evaluating the proposed standard, aligning with global best practices, and establishing a robust foundation for managing building information in Sweden's construction and urban planning sector. The incorporation of ISO 19650, as suggested by Eriksson (2020), proves instrumental in realizing these goals.

As an international standard, ISO 19650 focuses on enhancing information management in engineering projects by facilitating the precise clarification of project stakeholders' roles involved in the BIM process and ensuring the accurate and detailed determination of their requirements (Ashworth, 2023). This standard aims to promote transparency and prevent misunderstandings stemming from insufficient clarity or transparency (Ashworth, 2023). ISO 19650-1 outlines that the information management (IM) process involves two key roles: the "appointing parties" (those receiving information, such as owners or clients) and the "appointed parties" (those providing information, such as designers and construction contractors). Figure 2.2 shows the two key roles in the IM process according to ISO 19650.

Figure 2.2 The two key roles in IM process according to ISO 19650 (Source: UK BIM framework, Guidance Part D)

In line with the directives provided by the UK BIM framework (2020), it is emphasized that the appointing parties bear a critical responsibility in effectively conveying their requirements to the appointed parties. This communication should not only encompass the specific details of what is needed but also extend to articulating the desired outcomes. As highlighted in Guidance Part D (2020), these requirements may cover diverse aspects such as maintainability, operability, sustainability, security, safety, and risk management. The appointing parties play a pivotal role in specifying and defining these elements, ensuring clarity in their expectations. The comprehensive communication outlined by the UK BIM framework (2020) serves the purpose of aligning the work of the appointed parties with the overarching project objectives set by the appointing parties. This alignment is crucial for ensuring that the appointed parties understand not only the specific requirements but also the broader goals and outcomes expected from their contributions. This approach, as advocated by Guidance Part D (2020), establishes a framework for effective collaboration and coordinated efforts throughout the project lifecycle.

Conversely, the information providers (appointed parties) must be diligent in understanding the information that needs to be delivered promptly so they can deliver the necessary data in a timely and organized manner, which in turn ensures the owner's satisfaction and the fulfilment of their requirements, contributing to a successful project outcome (Sadrinooshabadi et al., 2021). By following the precise documentation and information exchange methods delineated in ISO 19650, all these crucial communication and information exchange practices can be efficiently embraced. ISO 19650 also underscores the importance of restricting information collection to what will genuinely be used, thereby averting wasteful practices (Ashworth, 2023).

ISO 19650 categorizes the information requirements into four distinct types; these information requirements offer dual advantages. Firstly, they establish the necessary information, outlining what is needed. Secondly, they serve as a valuable benchmark, enabling a comparison with the information delivered (UK BIM Framework, Guidance, Part D):

- **Organizational information requirements (OIR):**

OIR can be considered the highest umbrella for all subsequent plans and relationships that emerge from them. OIR plays a crucial role in providing a holistic view of the high-level information necessary for assets throughout their lifecycle. This, in turn, empowers the appointing party to operate their business effectively and efficiently while also gaining a clear understanding of the information demands of their clients and stakeholders.

However, the OIR encompasses information vital for fulfilling organizational reporting obligations and supporting strategic business endeavours, strategic asset management, portfolio planning, and regulatory obligations (Ashworth, 2023).

Throughout the operational and delivery phases of the asset's lifecycle, it is imperative to apply the principles and processes outlined in ISO 19650 to delineate information needs. This results in two specific information requirements: Asset Information Requirements (AIR) and Project Information Requirements (PIR), both originating from the OIR (UK BIM framework, Guidance Part D, 2020).

- **Asset Information Requirements (AIR):**

Asset Information Requirements (AIR) encompass data and information directly about the operational status of the asset, meeting the specific needs and demands of the asset owner/operator. Understanding these needs is paramount, and it's of utmost importance to identify and address these requirements during the initial stages of the design process. This ensures that the design aligns with these requirements throughout the facility's development until it reaches the desired operational stage. AIR, derived from the OIR, encompasses information essential for the effective management and maintenance of the constructed asset over its entire life span (Ashworth, 2023).

AIR can include incorporating relevant OIR, which may encompass corporate policies and guidelines, vigilantly monitoring the utilization and condition of the asset, keeping a close watch on energy consumption and operational costs, and catering to the information requirements of asset stakeholders, such as visitors or end-users (UK BIM Framework, Guidance, Part D, 2020)

- **Project Information Requirements (PIR):**

PIR pertain to the specific information needs associated with the design and construction phases of a project. In order to provide thorough guidance for these project phases, the appointing party initiates these requirements based on the OIR. PIR may encompass various elements according to (UK BIM Framework, Guidance Part D, 2020) those are including:

- ✓ Project Business Case: This may involve financial information to determine value for money and affordability.
- ✓ Strategic Brief: Outlining the high-level project objectives and strategies.

- ✓ Project Stakeholders: Identifying the individuals or entities requiring specific information during the project's execution
- ✓ Project Tasks: Defining the tasks and responsibilities that the appointing party will undertake as part of the project.

Figure 2.3 presents ISO 19650 requirements and how they are connected to each other.

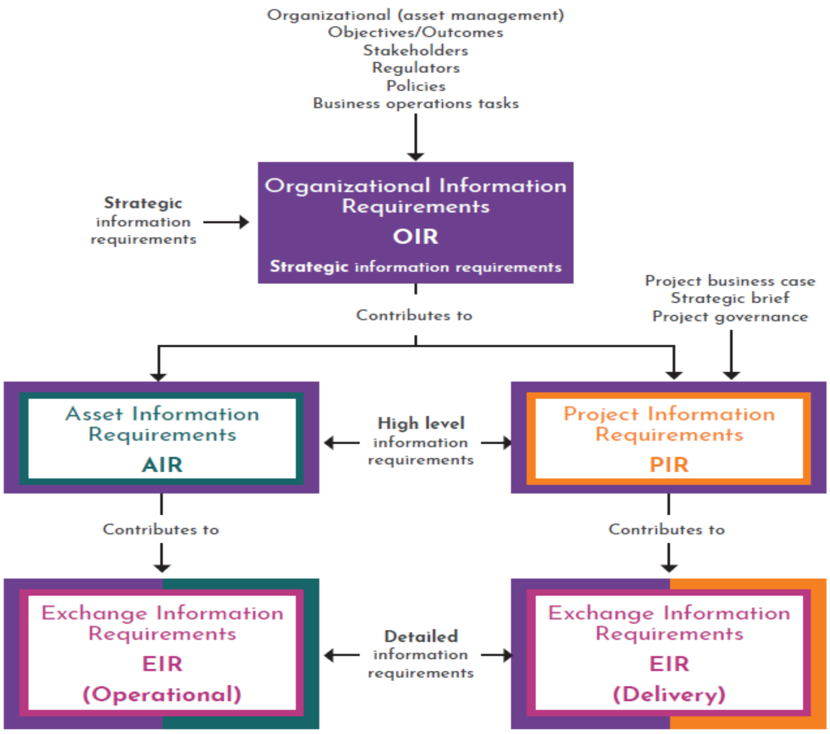


Figure 2.3 The ISO 19650 requirements and how they are connected to each other. (Source: UK BIM framework, Guidance Part D)

As illustrated in Figure 2.3, combining PIR with OIR and AIR, form the basis upon which the Employer's Information Requirements (EIR) are built.

- **Exchange Information Requirements (EIR):**

The EIR is a crucial component of the information delivery process in a BIM (Building Information Modelling) contract, and ISO-19650 specifically mentions it as such (Sanhudo et al., 2018). EIR outline the information that a lead-appointed party or an appointed party must deliver at each information exchange. It needs to be very clear about what information is needed, when it's needed, how detailed it should be, and in what format it should be presented. This helps the appointed party know what's expected and ensures that the client's expectations can be met when the project is handed over. The information requested should cover not just the basic shapes and designs but also other details about the building, like what materials were used and how environmentally friendly they are, for example, in terms of heat insulation and ecological impact (Ashworth, 2023). Also, making sure that the EIR clearly define operational information for facilities management is very important for figuring out the Construction Operation Building Information Exchange (COBie) deliverables and making it easier for facilities management to use BIM in more situations. The EIR outlines essential details for furnishing COBie data, with the overarching goal of expanding its usefulness to streamline building operation and maintenance (Said, 2023).

As indicated in Raslan et al. (2020), the EIR is described as a "pre-tender document" outlining the information to be provided and the standards and procedures that the supplier must adhere to throughout the project delivery process. Meeting EIR requirements necessitates the establishment of a collaborative relationship among stakeholders to effectively manage and communicate their respective needs. After the appointing party has specified its requirements, it is responsible for preparing three types of documents in response to the EIR. Figure 2.4 illustrates the relationship between information requirements and information models.

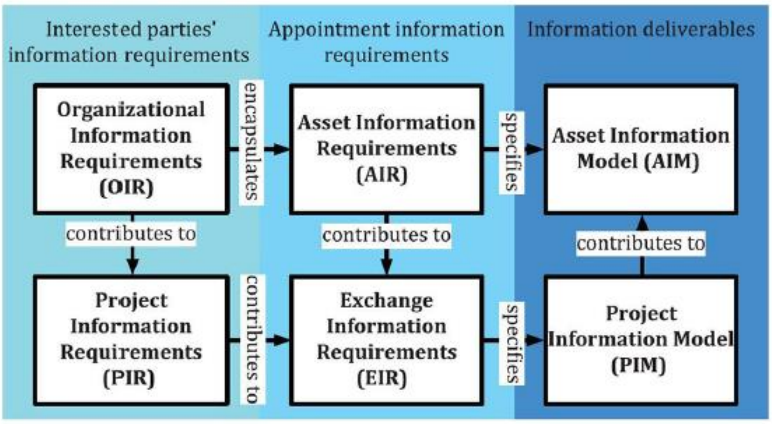


Figure 2.4 Relationship between information requirements and information models.

- **BIM execution plan (BEP):**

According to Ashworth (2023), the BEP holds a pivotal position in the progression of BIM projects, particularly concerning the creation, exchange, and management of data. The BIM execution plan is a response to the client's EIR. The EIR and the response provided by the appointed party in their BEP lay the essential groundwork for the successful implementation of BIM.

Ashworth (2023) mentioned that the BEP should include a well-defined process for data production that clearly outlines the roles, functions, processes, interfaces, interactions, and technologies involved. Additionally, the BEP can address various other critical aspects, such as the frequency and timing of meetings, collision checks, visualization of planning elements, quantity assessments, simulations of technical systems, considerations for the project's life cycle, and their respective schedules and extents. (UK BIM Framework, Guidance Part E, 2020) refer that the BEP serves dual purposes in facilitating the processes of tendering, appointment, and information delivery, it functions as a means of demonstrating to the party making the appointment that the potential delivery team has the capability to effectively handle project information in alignment with any specified information requirements. It also serves as a practical tool that the appointed delivery team can utilize throughout their engagement to generate, oversee, and share project information alongside various other resources (UK BIM Framework, Guidance Part E, 2020). According to (UK BIM framework, Guidance Part E, 2020) the Building Information Protocol within ISO 19650-2 recommends various key considerations for the preparation of the BEP These considerations include:

A) Identifying individuals responsible for information management is necessary to ensure competent personnel and resource planning.

B) Establishing an information delivery strategy, including how to meet EIR and objectives for collaborative information production.

C) Defining the federation strategy for information integration.

D) Creating a high-level responsibility matrix specifying responsible parties and deliverables for each element in the information model.

E) Suggesting additions or amendments to information production methods and procedures.

F) Proposing changes to the project's information standard.

G) Outlining the schedule of software, hardware, and IT infrastructure required for effective collaboration and interoperability.

- **The Project Information Model (PIM) and Asset Information Model (AIM):**

PIM and AIM are described by British standard institution "PAS 1192-2:2013 as complete sets of data that include both graphical and non-graphical information, as well as relevant documents for a building or construction project; These data sets are systematically stored and administered within a Common Data Environment (CDE).

AIM serves as a comprehensive information repository gathered from various sources to support effective asset management during the operational phase; AIM encompasses data that necessitates regular updates to accurately reflect any upgrades, repairs, maintenance, decommissioning, and refurbishments within the model (British standard institution "PAS 1192-2:2013).

In parallel, PIM initially comprises project-specific data, which, throughout the project's life cycle, undergoes updates to evolve into asset information, this transformed data ultimately becomes part of the AIM; Consequently, this approach allows for the centralized management and ongoing updates of pertinent building asset information within a single model (Raslan et al., 2020). Figure 2.5 illustrates the relationship between PIM, AIM, and other requirements.

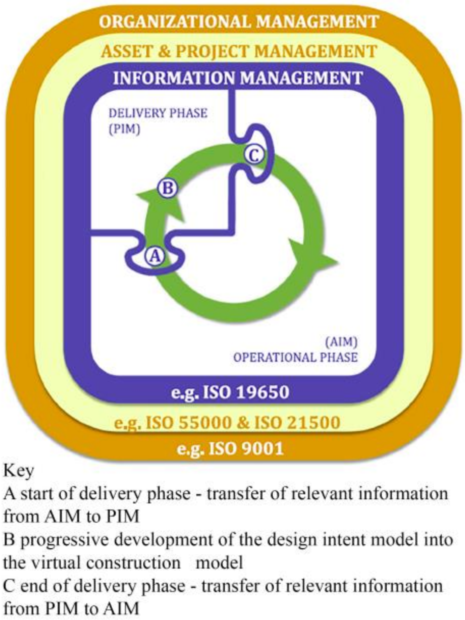


Figure 2.5 Relationship between PIM and AIM and other requirements.

In addition to following the requirement documents mentioned in ISO 19650, the Level of Information Needed (LOIN) concept provides a structured framework for precisely specifying the quality, quantity, and level of detail required in information. Its fundamental purpose is to ensure that the necessary amount of information is communicated without excess or shortage. This concept assists in determining the minimum information requirements for each specific purpose, avoiding any unnecessary or surplus data. Striking the right balance is critical, as both excessive and insufficient information specifications can pose risks to the efficient management of projects or tasks. Achieving the optimal level of information is essential for successful outcomes (UK BIM framework, Guidance Part D, 2020).

LOIN is a dynamic concept that is defined at different stages of a project's lifecycle. The appointing party, typically the client, has the authority to set the LOIN in various project phases. During the initial definition of AIR, the client establishes the LOIN, specifying the quality, quantity, and level of detail required; in the tender phase, the client can once again define the LOIN to clearly communicate their information needs. (UK BIM framework, Guidance Part D, 2020).

On the other hand, lead-appointed parties, such as designers, main contractors, or specialist manufacturers, also play a role in shaping the LOIN as the project progresses, for instance, the designer may set the LOIN during the preliminary design phase to guide accessibility analysis, while the main contractor may define the LOIN during the construction phase for health and safety analysis (UK BIM framework, Guidance Part D, 2020). Even a specialist manufacturer for a heritage project can contribute by defining the LOIN during the production phase and detailing what is necessary for 3D printing a replacement component; the flexibility of LOIN ensures that information requirements align with project objectives at every stage (UK BIM framework, Guidance Part D, 2020). Within this context, the level of information needed plays a pivotal role in elucidating the essential information requirements, clarifying their purpose, and specifying the structure and delivery methods (UK BIM framework, Guidance Part D, 2020).

2.3.3 The Lack of Common Work Environment

A prevalent problem in information management is the informal exchange of information, where those assigning tasks often communicate their needs in a casual manner, resulting in inefficiencies and misinterpretations (Sadrinooshabadi, 2021). Sadrinooshabadi (2021) highlighted the absence of a specialized platform to articulate and handle requirements, with verbal conversations and emails being the main modes of communication. Hence, his study emphasizes that the adoption of Common Data Environments (CDEs) is crucial.

A CDE refers to a shared digital workspace for a project, offering separate access zones for various project stakeholders; it includes precise status indications and a well-defined workflow explanation for efficient exchange and approval procedures (Preidel, 2018). CDEs can be adopted as a dedicated platform for expressing and managing requirements in the construction project and facility management context; it provides a collaborative solution that enables efficient and effective information exchange while enhancing clarity and consistency in information management (Preidel, 2018). Preidel (2018) highlighted that by implementing CDEs, organizations can reduce operational costs and promote efficient practices, enhancing decision-making and ultimately leading to increased success in project and facility management; also, the CDE platforms allow for structured information exchange, reducing the likelihood of misinterpretation and ensuring that all requirements are captured and properly documented. Moreover, it allows for effective monitoring and updates to the information platform, ensuring that relevant and up-to-date information is easily accessible to all relevant parties (Preidel, 2018).

Jaskula and Kokoris (2022) delved into the diverse spectrum of digital information storage methods employed by construction enterprises, these mechanisms mirror conventional computer file storage, yet are tailored explicitly to suit the intricacies of construction endeavours. Jaskula and Kokoris (2022) identified three distinct tiers:

• First Level: Fundamental storage solutions akin to Dropbox, characterized by simplicity and cost-effectiveness, albeit lacking in robust security measures.

• Second Level: Elevated storage options, meticulously organized and fortified for enhanced security.

• Third Level: Pinnacle storage solutions designed to impeccably manage construction data, boasting meticulous organization and seamless integration with intricate models.

Figure 2.6 Presents the framework for CDE maturity assessment by (Jaskula and Kifokeris, 2022).

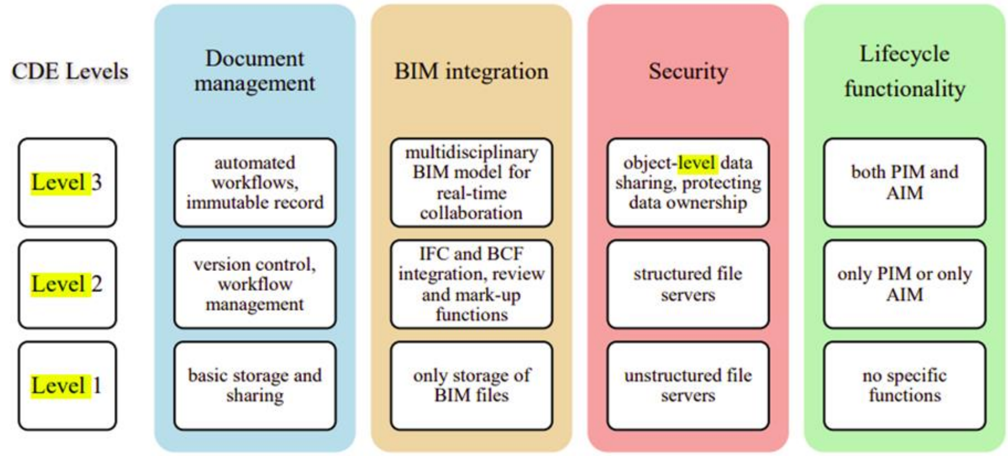


Figure 2.6 Framework for CDE maturity assessment.

In evaluating software solutions for Common Data Environments within the construction industry, a comprehensive comparison was conducted by Jaskula (2023), focusing on tools commonly utilized during the project planning and delivery stages. Insights from the NBS BIM Report 2020, as well as survey and interview responses from professionals in the industry, served as a guide for choosing these tools. Reviews from the Capterra online platform were also analysed and integrated with interviewee perspectives to gauge each platform's maturity based on a devised assessment framework; factors such as usage rates, pricing per user per month, and user ratings were considered to compile a comparative analysis as shown in Table 2.2 Furthermore, an online survey was administered to industry stakeholders to ascertain prevalent methods of information exchange and storage in construction projects (Jaskula, 2023). Jaskula (2023) findings indicated that email remains a primary tool for information exchange, while cloud-based repositories like Dropbox and Google Drive are widely adopted. Among specialized CDE solutions, Autodesk's BIM 360 emerged as a popular choice, offering real-time collaboration on shared BIM models and effective management of design and construction phases; Aconex by Oracle also stood out for its strong version control and data immutability features, although some respondents noted challenges related to cost, ease of use, and interoperability with other systems. Figure 2.7 presents the percentage use of different CDE solutions among survey participants.

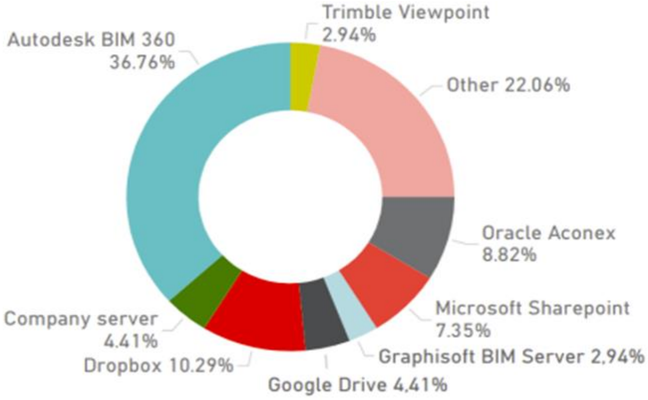


Figure 2.7 Percentual use of different CDE software among survey participants.

Table 2.2 Comparison of CDE platforms assessing their level of maturity (Bedoiseau et al., 2022; Das et al., 2021; Jaskula et al., 2022).

Name of the tool	User/month price	BIM survey users	Capterra rating	Document management	BIM integration	Security	Lifecycle Function ality
Autodesk BIM360 / ACC	£48 to £155	39%	4.3	Level 2	Level 3	Level 3	Level 2
Viewpoint 4projects (Trimble)	£15 to £50	50%	4.1	Level 3	Level 2	Level 3	Level 2
Aconex (Oracle)	£53 to £87	36%	4.4	Level 3	Level 2	Level 3	Level 2
Asite	From £375 per project	32%	3.6	Level 3	Level 2	Level 3	Level 2
ProjectWise (Bentley)	£49 to £145	18%	4.4	Level 3	Level 2	Level 3	Level 2
Deltek/ UnionSquare	n.a.	11%	2.8	Level 3	Level 2	Level 3	Level 2
Procore	From $375 (unlimited users)	5%	4.5	Level 3	Level 2	Level 3	Level 2
BIMcollab	£5 to £14	n.a.	4.3	Level 2	Level 3	Level 3	Level 2
Dropbox	£14 to £40	38%	4.5	Level 1	Level 1	Level 1	Level 1
SharePoint (Microsoft)	£4.10 to £22	36%	4.3	Level 1	Level 1	Level 1	Level 1
Google Drive	from £5	23%	4.8	Level 1	Level 1	Level 1	Level 1
One Drive (Microsoft)	£8.20 to £36	30%	4.5	Level 1	Level 1	Level 1	Level 1

2.3.4 Interoperability Challenges in the Construction Industry

Fragmentation resulting from the use of different tools and methodologies by various stakeholders throughout project phases poses significant challenges to interoperability in information management, as stated in the UK BIM Framework's Guidance Part B (2020). In the design and construction stages, a variety of software solutions are employed, and it's crucial to underscore that the primary value lies in the information itself rather than the specific software utilized (UK BIM Framework, Guidance Part B, 2020). These software tools are viewed as instruments, subject to change as the project evolves. However, maintaining accessibility and interpretability of information throughout the asset's entire lifecycle remains paramount. Failure to organize information in a structured manner may jeopardize interoperability, potentially requiring configuration efforts that could escalate costs and compromise information quality (UK BIM Framework, Guidance Part B, 2020).

To address these challenges, it is essential, according to the UK BIM Framework's Guidance Part B (2020) to ensure that information is structured in an open and consistent manner from the project's inception, this proactive approach is crucial in mitigating potential issues related to interoperability. By establishing a foundation of structured organization early on, project stakeholders can foster a more seamless flow of information, reducing the need for extensive configuration efforts and safeguarding against increased costs and compromised information quality (UK BIM Framework, Guidance Part B, 2020).

Open Data has gained substantial recognition due to its capacity to facilitate the seamless exchange of information, spanning from the design and construction phases to the facilities management stage (Said, 2022). Open data encompasses information that is available and usable by everyone, permitting unrestricted reading, sharing, reusing, republishing, and redistributing, conversely, proprietary data is restricted to specific software solutions, constraining its accessibility and usability (UK BIM Framework, Guidance Part B, 2020). Furthermore, the use of open data holds significant importance, particularly in archiving, as it directly impacts the methods employed for recording and storing information (UK BIM Framework, Guidance Part B, 2020. Assets, such as buildings and infrastructure, often have extended lifespans, as emphasized by the UK BIM Framework's Guidance Part B (2020), however, there is no guarantee that future software solutions will remain compatible with or capable of interpreting proprietary data related to these assets; therefore, the adoption of open data practices emerges as a practical solution to address this potential compatibility issue (UK BIM Framework, Guidance Part B, 2020).

Playing a central role in the digital transformation of the built environment, Building SMART, as an international non-profit organization, is a key advocate for open, worldwide standards and solutions aimed at elevating infrastructure and building projects. Their mission revolves around fostering the adoption of open data principles within the industry; notable contributions from Building SMART including initiatives like IFC (Industry Foundation Classes), MVD (Model View Definitions), and BCF (BIM Collaboration Format), have been instrumental in advancing the industry's commitment to open data practices, as highlighted in the UK BIM Framework's Guidance Part B (2020).

IFC serves as an open data format designed to streamline the exchange of building information among various software systems utilized in the realms of design, construction, and facility management (Said, 2022). The preference among software vendors is to provide direct or proprietary methods for exchanging data, as Redmond (2012) highlighted, however, there is an alternative approach through public product data model exchange formats; these formats are characterized by their openness and management within the public domain. Examples of such formats include XML, text files, and IFC. The International Alliance of Interoperability was notable for leading the development of IFC as an interoperable solution. IFC is an outcome derived from the Building Construction Core Model and has been nurtured within the International Standards Organization (ISO) 10303 framework, formally recognized as the Standard for the Exchange of Product Model Data (Redmond, 2012).

2.3.5 Inefficient BIM Usage in the Operations and Maintenance Phase

As mentioned before in the challenges section, focusing on BIM-enabled practices primarily in the design and construction phases. Cavka, (2017) investigated and proposed a method to help large owners in the construction industry develop and formalize information requirements essential for efficient project delivery and asset management through BIM. The study recognized that while BIM has shown considerable value in the design and construction phases, its potential for enhancing asset management throughout the asset lifecycle remains underutilized. The primary challenge addressed was the difficulty owners face in clearly defining, formalizing, and ensuring compliance with BIM requirements.

In the domain of Facility Management (FM), efficient information management holds paramount importance, as highlighted by Said (2023). The precision and availability of data, extending from the initial design and construction stages to the continuous Operations and Maintenance (O&M) phases, play a crucial role in ensuring streamlined FM operations and are indispensable for facilitating well-informed decision-making processes (Said, 2023).

The adoption of Open BIM standards, specifically COBie and IFC, is presented as a practical approach by Said (2023) to streamline the information flow across the design, construction, and facility management phases. These Open BIM standards primarily concentrate on achieving two critical objectives: improving the exchange of facility and asset data and enhancing information management within facilities management systems (Said, 2023). Notably, the inclusion of COBie becomes particularly significant, acting as a key component for the smooth and efficient operation of facility management in a BIM-centric environment (Said, 2023).

In the context of construction and FM, COBie serves as a structured data format, typically in the form of a spreadsheet. It contains essential information necessary for project commissioning, ongoing operation, and maintenance. This data is subsequently provided to the employer or operator for use in decision-making tools, facilities management systems, and asset management systems. (British standard institution, PAS1192-2-BIM). Bill East established the COBie standard in 2007. Its primary aim is to standardize the exchange of building lifecycle information. The COBie protocol offers a well-structured and easily comprehensible framework for conveying facility data, especially when it comes to streamlining the maintenance and operational phases within the facility's lifecycle (East, 2007). The COBie standard provides a streamlined way to gather and share facility management information in an organized manner right from the start of a construction project. Essentially, it functions as a data bridge connecting the BIM model and the Computer-Aided Facilities Management (CAFM) system. This involves exporting asset data from the model into a spreadsheet and subsequently importing this sheet into any BIM-compatible CAFM system during the initial stages of the operations phase (Alnaggar & Pitt, 2019).

The integration of Building Information Modelling (BIM) has imposed a necessity for facilities management teams to explicitly outline their asset data requirements as an essential element of COBie data preparation during all pre-operational phases of a building's life cycle, as articulated by Alnaggar and Pitt (2019). These specifications are encapsulated within the Asset Information Requirements (AIR) document, a responsibility assigned to the facilities management team. According to Alnaggar and Pitt (2019), this document should encompass a comprehensive list of all assets controllable within the building. Moreover, it is imperative that the AIR document delineates the key attributes for which the construction supply chain holds responsibility throughout the building's lifecycle (Alnaggar & Pitt, 2019). The responsibility for creating COBie deliverables rests with the employer, the project team, and the supply chain. They are tasked with establishing a collaborative information exchange framework that ensures the smooth and continuous flow of information throughout the entire lifecycle of the facility (Said, 2023).

In contrast to the conventional ad hoc method of information sharing in facility management, East and Nisbet's (2010) study outlined a method to assess the cost savings made by adopting COBie for information exchange. Their findings highlighted that the utilization of COBie could potentially result in cost reductions of up to 75% when compared to the overall expenditures linked to ad-hoc information systems for the identical buildings. The COBie framework comprises nearly all the essential data necessary for efficient asset management during the operational phase. It includes details regarding the building's spatial layout, elucidating the connections between various floors, zones, and spaces. Additionally, it provides insights into the building systems, their components, and their interrelationships with the corresponding areas they occupy (Cavka et al., 2017). At the asset level, COBie encompasses a wealth of invaluable data pertaining to assets, rendering it exceptionally significant during the operations and maintenance phases. For instance, it comprises physical attributes of assets like dimensions (length, width, and height) as well as operational particulars such as power consumption, voltage specifications, warranty details, and supplier information (Alnaggar & Pitt, 2019). This methodical approach to organizing and maintaining data flow throughout the building's lifecycle underscores its pivotal role, necessitating efficient collaboration among all stakeholders to generate a high-quality COBie dataset that proves practical for facility managers during the operational phase of the building's life cycle (Alnaggar & Pitt, 2019).

In accordance with the project management principles of the Project Management Institute (PMI) and the RIBA (Royal Institute of British Architects) Plan of Work, the COBie Management Project (CMP) is organized into distinct and well-defined phases:

1. Initiation Phase: The primary goal in this phase is to precisely define the scope of the COBie management project, deciding what information to include in the COBie deliverable and what to exclude. The COBie data requirements' scope is detailed in the AIR. This emphasizes the importance of adopting COBie from the project's start, aligning with specified requirements across all project stages, and preparing for seamless integration during delivery and operational phases. The scope includes:

- A list of manageable assets.
- Specified attributes for each asset.
- Zoning strategy for space grouping.
- Classification standard.
- Asset naming conventions.
- Excluded data and delivery plans.
- Software tools for data coordination.

2. Planning Phase: Following the scope definition, the architect leads the development of a comprehensive COBie management plan. This plan contains crucial information for the construction supply chain to execute the defined scope effectively. It outlines clear roles and responsibilities for all stakeholders and presents a structured COBie schedule. This structured data can be a valuable resource for future research, analysis, and decision-making.

3. Execution Phase: In this phase, the majority of asset data intended for the COBie format should be accessible and prepared for the population in the COBie dataset by the phase's conclusion. The main contractor, in collaboration with the construction supply chain, is primarily responsible for delivering the final COBie dataset.

4. Closeout Phase: During this phase, the main contractor, along with the architect and the client's FM team, conducts a thorough quality assessment of the COBie data. The aim is to ensure alignment with the building's operational requirements and to make necessary adjustments or additions to the final COBie deliverable before uploading the data into the CAFM system.

3 Chapter Three: Methodology

3.1 Introduction to Methodology

In this chapter, we elucidate our methodology for uncovering challenges in information management throughout the project life cycle within the construction industry and proposing mitigating strategies for those challenges within the framework we are going to devise. Our methodology is grounded in a dual-pronged research approach, which employs interviews and literature-derived data. We initially turn to the existing literature to generate pertinent questions for our interviews. However, during the interview process, we tailor and refine the information gleaned from the literature to ensure its relevance to our investigation. Qualitatively, an extensive literature review is conducted, and a qualitative analysis of the data collected from the interviews is performed. This holistic approach provides a thorough understanding of the challenges, culminating in the development of a robust framework.

3.2 Data Collection Methods

3.2.1 Literature Review

For the literature review we had followed the methodological guideline of Webster and Watson (2002) The study commenced with a comprehensive review encompassing academic papers, reports, and pertinent industry literature. The data sources encompassed Google Scholar and the Chalmers library, ensuring a reliable and scholarly foundation for the investigation. The initial phase involved systematic searches aimed at identifying prevalent challenges related to information management within the construction sector. By following a structured method, we were able to get a basic understanding of the industry's main problems. This led us to research relevant literature that suggested possible solutions to these problems. A rigorous filtration process was subsequently employed to isolate challenges deemed to possess the most profound impact on information management, effectively streamlining the focus to prioritize critical issues.

The emphasis was placed on ensuring the selected literature retained contemporary relevance, eschewing outdated sources. This scrutiny encompassed an exploration of contemporary methodologies specifically designed to address the prevalent challenges inherent in achieving effective information management within the construction industry. The main goal was to find new approaches that have been studied and used to deal with these problems. This would give a modern and well-informed look at how information is managed in the construction industry. The data acquisition process remained meticulously curated, primarily relying on Google Scholar, to accentuate the latest advancements and pertinent progressions within the field. The initial search endeavours were carefully tailored to isolate contemporary challenges related to information management, serving as the foundational underpinning for subsequent inquiries into contemporary solutions. Transitioning into the subsequent phase, the study advanced to formulate interview inquiries grounded in the knowledge gleaned from extant literature.

3.2.2 Interviews

The next step in data collection involved conducting semi-structured interviews with key stakeholders, encompassing professionals from construction companies, experts in information management, and relevant project stakeholders. We conducted a total of eight (8) interviews, all of which were conducted online and lasted approximately one 1 hour each. These interviews featured a diverse group of experts from different companies, including both large and medium-sized enterprises. The interviewees had backgrounds in civil engineering and architecture, ensuring a comprehensive representation of expertise within the industry.

The interview questions were thoughtfully designed to extract insights pertaining to the challenges encountered and potential solutions influencing the attainment of effective information management within construction projects. In formulating these inquiries, emphasis was placed on three primary aspects: firstly, to inquire about how the identified challenges, as collated from the literature, manifested in practical settings, moving beyond theoretical implications. Additionally, the interview sought to explore whether the interviewees had first-hand experiences or were adversely affected by these challenges, substantiated by illustrative examples. Secondly, the line of questioning delved into the actions taken by the interviewees to mitigate these challenges and the ensuing success of these mitigation efforts. Lastly, the interviews incorporated suggestions gleaned from the literature regarding potential solutions, prompting the interviewees to assess their familiarity with these proposals and whether they had encountered or acknowledged their efficacy in facilitating effective information management. Furthermore, during the interviews, special attention was given to encourage interviewees to share any significant challenges from their professional experiences that may not have been covered in the initial literature search. This step was crucial to ensure that no significant challenge affecting information management was overlooked, and to gather a comprehensive understanding of the issues faced in practice. Table 3.1 Present details about the interviewees.

Table 3.1 Interviewees details

Interviews Number	Interviewees position	Years of Experience	Company size	Company Role
1	BIM Coordinator	15 Years	Medium	Appointed party
2	BIM Coordinator	30 Years	Large	Appointing party
3	BIM Manager	25 Years	Large	Lead appointed party
4	BIM Manager	20 Years	Large	Lead appointed party
5	BIM Project Manager	5 years	Medium	Appointed party
6	BIM Project Manager	15 years	Medium	Appointed party
7	BIM Strategist	8 years	Large	Appointing party
8	BIM Strategist	8 years	Medium	Appointed party

3.3 Data Analysis and Framework design

After collecting data from both the literature and interviews, we proceeded to the next stage, involving data analysis. Our analysis commenced with a comparison between the primary challenges identified in the existing literature and the practical scenarios that surfaced during the interviews. In this phase, we aimed to bridge the gap between theoretical insights from the literature and the real-world situations within the construction industry. This comparison allowed us to gain a deeper understanding of how these challenges manifest in practice and to identify any nuances or deviations from theoretical expectations.

The subsequent step in our analysis entailed comparing the solutions proposed in the existing literature to address each of the identified challenges with the insights gleaned from the interviews. This comparative assessment sought to determine the practicality and effectiveness of these proposed solutions from the perspective of the interviewees. By aligning theoretical solutions with the practical perspectives provided by interviewees, we assessed the applicability and feasibility of these solutions in the context of the real-world challenges faced by industry professionals.

In the final stage of our analysis, guided by the insights obtained from the previous step, we selected practical solutions to incorporate into our framework. We took into consideration the recommendations provided by the interviewees and conducted additional research to explore supplementary solutions for addressing information management challenges. These chosen solutions were then integrated into our proposed framework, ensuring that it was well-informed by both existing literature and the practical perspectives of industry professionals. This comprehensive approach is designed to establish a robust framework for efficient information management in the construction industry, aligning closely with the real-world needs and challenges identified during the interview process. The proposed framework will be firmly rooted in the principles and guidelines outlined in the ISO 19650 standard. It will also provide solutions and recommend tools to facilitate the seamless implementation of the ISO 19650 standard. Figure 3.1 illustrates the steps that were followed in this study.

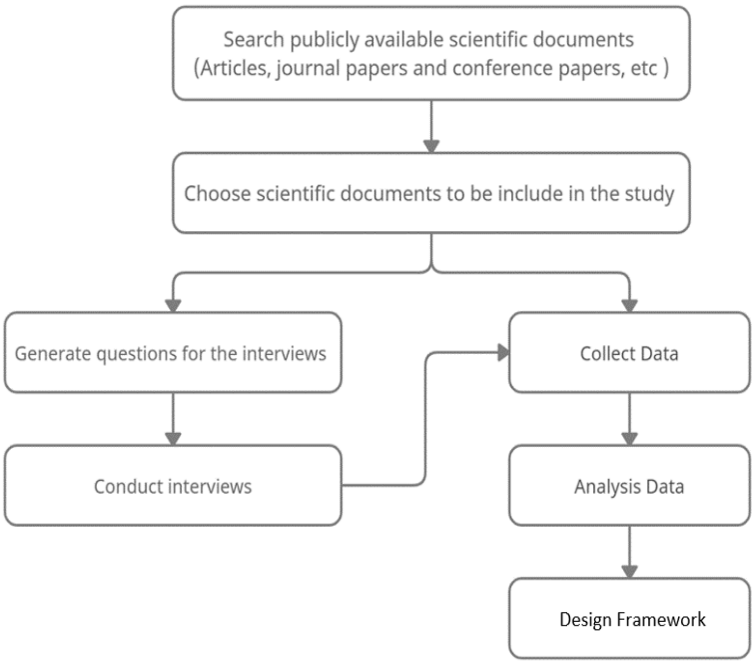


Figure 3.1 Study methodology flowchart

4 Chapter Four: FINDING AND RESULTS

4.1 Introduction

According to existing literature and interviews, the current digital landscape presents organizations with a significant influx of data and information. This surge in data offers the potential for improved decision-making and operational efficiency. However, it also introduces significant challenges in information management, making the effective organization and utilization of data a critical component of modern business operations.

In order to address the complex world of contemporary information management, this chapter first identifies these challenges and then delves into creative solutions and strategies informed by a thorough literature review and surveys. Recognizing the pivotal role of standardized BIM information in mitigating these challenges, our research aims to propose a well-structured framework. Drawing insights from our comprehensive literature review and stakeholder interviews, this framework is tailored to manage the complexities involved in information management for construction and built asset projects. It is envisioned as a practical and user-friendly tool, intended to empower industry professionals. In the ever-evolving realm of construction and built asset projects, where a multitude of stakeholders come together to shape the physical infrastructure that supports modern society, the effective management of information holds paramount importance. The success of these projects pivots on the stakeholders' capacity to communicate, cooperate, and make well-informed decisions. This challenge becomes progressively intricate as projects increase in scale and complexity.

To address these challenges, the ISO 19650 standard has emerged as a guiding light, providing clarity and efficiency. Grounded in globally recognized principles, ISO 19650 furnishes a standardized framework for information management in the construction industry. It transcends mere rule-setting, presenting a holistic approach that promotes transparency, streamlines operations and facilitates seamless collaboration among stakeholders. The cornerstone of our proposed framework will find its firm foundation in the principles and guidelines delineated by the ISO 19650 standard.

4.2 Findings

4.2.1 Identifying Challenges and Barriers Hindered Effective Information Management

Based on the literature we have read we have chosen the challenges which have a huge impact on achieving effective information management. Those challenges included:

1. Resistance to Adopting New Industry Standards.
2. Misunderstandings and Conflicts Due to Unclear Requirements.
3. Lack of Common work environment.
4. Interoperability Challenges and Inefficient Information Exchange.

5. Inefficient BIM Usage in the Operations and Maintenance Phase and overload data.

When we inquired with the interviewees regarding these challenges, they confirmed that each one of these issues occurs in almost every project, resulting in significant delays and a continuous waste of time and effort. The challenges noted above are going to be addressed in more detail below.

4.2.2 Main Finding from Interview for Each Challenge

4.2.2.1 Regarding Resistance to Adopting New Industry Standard, tools and approaches

From the interviewees' perspective, resistance within the organization, particularly from upper management, proves to be a significant challenge. The resistance often stems from a lack of conviction in new tools or approaches aimed at enhancing information management. Convincing upper management of the importance and benefits of these changes is an ongoing struggle. The interviewees highlighted the necessity to effectively communicating the potential cost savings or advantages that these changes could bring to the project. He acknowledges that convincing middle management can facilitate the acceptance of these changes by the upper management, as they often rely on the expertise and recommendations of the middle management. However, implementing substantial changes, especially if they incur costs, requires extensive discussions and meetings to gain approval. They also mention that after many years in the industry, pushing for changes can sometimes be monotonous, and persistence and determination are key to driving change within the organization. Despite the resistance, he remains hopeful and emphasizes the importance of continuous efforts to bring about positive transformations.

Additionally, in the context of resistance to new standards and methodologies designed to enhance information management, insights emerged during an interview that underscored the human element in change processes. The interviewee emphasized that resistance, a common occurrence, is intricately linked to innate human traits and concerns. It was articulated that resistance often arises from a combination of factors, such as the fear of failure in adapting to new standards and apprehensions about the ability to apply them correctly. The interviewee also noted that the rapid introduction of successive changes can be particularly overwhelming and frustrating, posing a significant challenge, especially without adequate time for adaptation. This aligned with another interviewee, who highlighted the importance of time in the change process. Allowing individuals and organizations sufficient time to adjust and acclimatize to new standards was deemed crucial, with rushed change initiatives exacerbating resistance. Success stories showcasing tangible positive outcomes were emphasized as powerful motivators for individuals to embrace change. Furthermore, the interviewee advocated for patience and effective communication as essential components in addressing resistance. Engaging with individuals invested in the change and those directly impacted by it, while listening to their concerns and providing ongoing support, was seen as vital in facilitating change acceptance.

A prevailing consensus among the interviewed participants reflects a unanimous perspective on the predominant factor driving commitment to and compliance with new standards within the construction industry. This consensus highlights the crucial role that state authorities played in requiring these standards as fundamental prerequisites for any construction project. Within the purview of our research, particular attention was devoted to the resistance encountered in the context of embracing the ISO standard, and the consequent reliance on alternative approaches for meeting regulatory and educational requisites. Notably, the exploration of this subject uncovered a recurring theme – resistance to the integration of ISO standards. The primary rationale expressed for this resistance was the perception that these standards are intricate and challenging to decipher. Furthermore, respondents commonly noted the absence of any inherent motivation to embrace ISO standards, except when compelled to do so, typically by clients specifying such requirements.

4.2.2.2 Regarding Misunderstandings and Conflicts Due to Unclear Requirements

Most interviewees strongly supported the idea of using shared guidelines and rules for companies. This consensus reflected the belief that standardization guarantees uniformity in data and information management, thereby simplifying collaboration among diverse organizations in project endeavours. When companies independently devise their standards, it inevitably engenders compatibility issues. This lack of uniformity fosters confusion and misconceptions, compounding difficulties when divergent companies collaborate. Inevitably, this results in discord and disputes as team members from different organizational backgrounds may not share a common understanding of project requirements. Another pervasive issue arising from diverse standards is the creation of communication gaps. These gaps have the potential to disrupt the effective transmission of requirements and expectations among team members, thus exacerbating the likelihood of conflicts.

Furthermore, interviewees with academic backgrounds, leveraging their educational backgrounds, underscored the additional advantages associated with standardization. A shared set of standards reduces the necessity for extensive customizations and adaptations, streamlining project management, data sharing, and communication. This streamlined approach, in turn, contributes to increased operational efficiency while concurrently curbing the prevalence of errors and misunderstandings that tend to manifest when companies independently devise their standards. Furthermore, the adoption of industry standards can assist companies in circumventing legal entanglements and ensuring compliance with industry regulations. Interviewees affiliated with international companies further emphasized that these uniform standards facilitated collaboration with global partners, clients, and organizations. The ubiquity of recognized standards ensured a seamless alignment in global business interactions.

Interviewees emphasized the critical importance of establishing a standardized foundation for BIM, advocating for a universal set of requirements rather than each company creating its own custom BIM manual. These requirements encompass vital elements such as identification (ID), basic descriptions, and properties necessary for functions like clash detection and quantitative take-offs. By adopting a standardized approach, they aim to boost consistency and promote interoperability across various software platforms. This standardized approach aligns with the benefits of using a single industry standard, like ISO 19650, which ensures that all companies work with a common framework. This allows companies to streamline their BIM processes, eliminating the need for complex, customized BIM manuals. Instead, they can refer to and align with these foundational standards, enhancing efficiency and reducing errors. However, despite the theoretical knowledge of how standardization can streamline processes, the absence of a centralized authority to enforce these standardized structures has hindered their widespread implementation in Sweden. Interviewees also referenced a Swedish project known as "Beast," which is dedicated to standardizing digital workflows and practices in the construction industry. This initiative underscores the ongoing efforts to promote standardization and effective digital workflows in construction projects. These challenges highlight the significance of having one common industry standard that all companies can follow, which would ensure uniformity and enhance the adoption of efficient practices in the construction sector.

Following ISO 19650 (to ensure clear information and requirements exchange)

Drawing insights from the literature, it is evident that well-defined regulations and standards are vital in the realm of BIM to ensure a shared understanding of roles and expectations among all involved parties. ISO 19650-1:2018 serves as a cornerstone for these regulations, providing guidance that facilitates efficient collaboration and establishes clear directives for universal adherence. This standard emphasizes the collective definition of information prerequisites in collaboration with stakeholders throughout the project's lifecycle. Incorporating literature-based perspectives, embracing international standards like ISO 19650 in Sweden for building information management presents significant advantages. Aligning with globally recognized standards is crucial, given the emphasis on established international standards and their widespread software implementation, establishing a robust foundation for effective building information management in Sweden's construction and urban planning sectors.

Insights from interviews showcase diverse opinions regarding adherence to ISO 19650, ranging from opponents to advocates. Some interviewees express skepticism, viewing ISO 19650 as theoretical and cumbersome, suggesting its application mainly in international projects. They propose an alternative approach, prioritizing practicality and flexibility over strict adherence to ISO 19650. A suggested alternative is a Swedish version or an alternative standard to address unclear requirements and enhance stakeholder communication in the BIM process. Despite varied perspectives, there is a consensus on the necessity for a standardized foundation for BIM models, advocating for a fundamental set of requirements rather than each company creating its own BIM manual.

On the other hand, some interviewees acknowledged the advantages of ISO 19650, seeing it as a potential solution to conflicts arising from unclear roles, and thought of the value of having a standard like ISO, stating that it provides a basis for discussion and clarity, enabling reference to a set standard during conversations and decision-making. However, they found it challenging to follow due to its complexity and the time required to comprehend it. They recommended a Swedish-translated version and comprehensive guidelines to ease its usage, particularly for larger companies in Sweden. Lastly, some interviewees strongly advocated for adopting ISO 19650, citing its numerous benefits. They highlighted its alignment with digital transformation in the construction industry, offering a standardized framework for managing digital information in projects. ISO 19650 addressed traditional workflow challenges, such as miscommunication, delays, extra costs, and errors, by providing a structured approach to information management, enhancing efficiency and accuracy.

Furthermore, ISO 19650's emphasis on standardization and interoperability was acknowledged, facilitating consistency and compatibility across projects and organizations. It promotes effective collaboration and communication by guiding information flow throughout the project lifecycle. The international collaboration aspect of ISO 19650 was seen as highly beneficial, fostering a common language and framework for information management and allowing remote teams to work efficiently and harmoniously. Moreover, ISO 19650 was viewed as empowering employers and clients, highlighting their role in setting information requirements and influencing digital collaboration, ultimately improving project deliverables' quality. The standard was seen as a systematic solution to industry-specific challenges, addressing issues like uncoordinated drawings, information disarray, delays, and budget overruns, ultimately enhancing project outcomes. Last but not least, ISO 19650's standardization has paved the way for training and certification opportunities. Professionals can undergo training aligned with ISO 19650, enhancing their understanding and proficiency in implementing BIM and related processes in line with the standard.

4.2.2.3 Regarding Lack of Common Work Environment

The interviewees unanimously underscore the importance of CDE platforms, such as BIM 360 and BIM Collaborate, in the realm of efficient information management. They draw a parallel between CDEs and the act of organizing and tidying up your desk, stressing the significance of placing everything in its rightful spot. In their collective opinion, CDEs act as catalysts for maintaining an orderly flow of information, ensuring the retention of a centralized and traceable data history.

However, amidst their recognition of CDE's indispensability, they candidly acknowledge a set of challenges that come hand in hand with these platforms. A key issue they highlight pertains to certain CDE platforms boasting proprietary features that complicate integration with other software, particularly those not affiliated with the parent company. This potential hindrance to seamless data exchange and collaboration doesn't go unnoticed. Nevertheless, the interviewees maintain a steadfast belief in CDEs as a necessary and vital element of the industry, particularly in the context of structured workflows and effective information management, especially for larger-scale projects. In their ideal collaborative environment, the interviewees advocate for open standards, specifically emphasizing the importance of IFC. They perceive IFC as a common language that transcends software boundaries, allowing different software tools to effortlessly exchange information. To address the integration challenges posed by proprietary features, they endorse CDE platforms that prioritize interoperability and support the IFC file format. Such a preference for open standards is consistent with their vision of a CDE that enables data exchange and collaboration without any difficulty, irrespective of the various software applications used by project stakeholders.

In addition, based on the explanation of the CDEs level mentioned in Ch2 (literature review) it is evident that some companies, as indicated by the interviewees, continue to operate at the foundational Level 1 of CDEs. They rely on basic tools like Dropbox for information and model exchanges. This preference is attributed to various factors, with some senior managers expressing confidence in this approach and asserting its sufficiency. Others argue that implementing CDE in complex projects poses challenges, while it is more manageable in smaller projects with fewer stakeholders, as data management and centralization are less intricate. However, it is essential to underscore that CDE usage is encouraged due to its significant benefits. To harness these advantages, a critical need exists for enhancing information management skills. Comprehensive training is vital for all stakeholders, including clients, designers, contractors, and subcontractors, to grasp the benefits of CDEs and learn how to use them effectively. Lastly, some stakeholders are hesitant to adopt CDEs for security reasons. They harbour concerns about potential conflicts arising from data privacy and ownership issues when utilizing cloud-based CDEs.

4.2.2.4 Regarding Interoperability Challenges and Inefficient Information Exchange

In our interviews, a unanimous consensus emerged concerning the challenges related to data interoperability. Interviewees confirmed that difficulties arise in the seamless exchange of data, primarily due to the fact that each specialist employs distinct software programs, each with its own unique file format suffix. These specialized file formats often necessitate dedicated software for access, rendering data exchange cumbersome. Notably, it was observed that this issue becomes particularly acute in large-scale projects, where compelling various specialties to adhere to a single software solution proves to be a formidable challenge. Within this context, it was recognized that employing open file formats offers a viable solution to these interoperability issues, facilitating smooth data exchange and enhancing communication among stakeholders. However, one interviewee cautioned that while open file formats play a crucial role, there can be occasional drawbacks associated with the potential loss of certain information. Additionally, it was emphasized that the selection of the correct version of IFC is imperative to mitigate any adverse effects.

During our interviews, it became apparent that the IFC file format held a prominent position, being well-known and widely utilized by the majority of participants for several years. In contrast, the second open file format, BCF, designed for issue sharing and resolution, garnered less recognition among a broader audience. People involved in clash detection activities were the ones who acknowledged it the most. Significantly, a key point raised by one of our interviewees underscores the utmost significance of embracing open file formats, especially within international projects. In these scenarios, the adoption of open formats is commonly stipulated right from the project's initiation as an integral component of specified requirements.

4.2.2.5 Regarding Inefficient BIM Usage in the Operations and Maintenance Phases

The interviewees' insights align with the challenges discussed regarding the common issue of data emphasis on design and construction phases, often neglecting the essential information required for operation and maintenance. One specific example underscores the significance of clear project requirements from the outset. The interviewee mentions a project involving a large kitchen department, where information model requirements evolved over three years. Changes in facility management systems, unforeseen initially, necessitated adjustments in the BIM model to meet new demands post-project completion. This lack of clear, consistent requirements resulted in conflicts over deliverables and scope, emphasizing the need for precise project requirements from the project's initiation.

Furthermore, the interviewees highlight the challenge of future facility managers' limited understanding of effectively utilizing digital building models, drawing from their years of experience. Historically, facility managers have posed bottlenecks in the process due to their struggles with available software and models. The lack of standardization, particularly in the Swedish context where digitalization commenced early without proper standardization, is also emphasized. This lack of industry-wide standardization has led to divergent approaches and practices. The interviewee underscores the importance of a structured and standardized approach to data collection across the project lifecycle. Such an approach would ensure comprehensive, accessible, and usable data not just during design and construction but throughout the building's lifecycle, including operation and maintenance phases. This standardization would enhance efficiency, foster better collaboration, and enable seamless data utilization at various stages of the building's life.

When addressing potential solutions for the challenges discussed, the concept of COBie emerged as a notable solution based on insights gathered from the literature and its recognized benefits. COBie is regarded as a means to standardize and structure data, akin to various classification and tagging systems commonly used in the construction industry. It is designed to facilitate efficient information management and sharing throughout a project's lifecycle. However, some of the interviewees point out that while COBie has merits for information administration and exchange, it may not necessarily simplify processes significantly. The impact of its implementation can vary based on project specifics and the extent to which all stakeholders embrace it.

Notably, some interviewees mentioned that NCCIFC, a classification framework specific to the Nordic region, is the prevalent system in Sweden. NCCIFC primarily focuses on data classification and organization during the construction process. In contrast, those interviewees familiar with COBie acknowledged its utility, particularly for the operation and maintenance phases of a building's life cycle.

Interestingly, a few of the interviewees were initially unfamiliar with COBie. Nonetheless, after receiving an explanation of its purpose and the associated benefits, they began to recognize its potential as a valuable solution. They understood that COBie could play a role in simplifying access to vital data for operation and maintenance, streamlining information within BIM pertaining to these phases, and possibly minimizing the inclusion of extraneous data. This highlights the significance of raising awareness about COBie and its practicality in enhancing data management across the spectrum of construction and building lifecycle processes. Table 4.1 illustrates the main finding we gain from the interviews regarding each challenge.

Table 4.1 Main finding gained from the interviews regarding each challenge

Category	**Interviews Key Findings**
Challenge 1 Resistance in Adopting New Industry Standards	- Upper management resistance due to lack of conviction. - Resistance linked to human traits, fear of failure, and rapid changes. - Allowing sufficient time for adjustment is crucial. - Success stories and effective communication motivate change. - Authorities play a pivotal role in mandating standards. - Resistance to ISO standards due to complexity and lack of inherent motivation.

Challenge 2 Misunderstandings Due to Unclear Requirements	- Support for shared guidelines and rules for companies to guarantee uniformity in data and information management. - Lack of uniformity in independently devised standards leads to compatibility issues and confusion. - Communication gaps arise, disrupting the transmission of requirements among team members. - Academic backgrounds emphasize advantages of standardization, reducing customizations and adaptations. - Importance of a standardized foundation for BIM models, advocating for universal requirements instead of individual company manuals. - Theoretical knowledge of standardization benefits hindered by the absence of a centralized authority for enforcement in Sweden.
FOLLOWING ISO 19650	Varying perspectives on ISO 19650, from scepticisms to strong advocacy: - Scepticisms based on its theoretical and cumbersome nature, suggesting a Swedish version or alternative standard. - Acknowledgment of its advantages but challenges in complexity and time required for comprehension. - Recommendations for a Swedish translated version and comprehensive guidelines for ease of use. - Advocacy for ISO 19650, citing benefits like enhanced efficiency, accuracy, and interoperability. - ISO 19650 seen as a systematic solution to industry-specific challenges, enhancing project outcomes. - Standardization led to certification and training opportunities aligned with ISO 19650 for professionals.
Challenge 3 The Lack of Common work environment	- Unanimous agreement among interviewees on the crucial role of CDE platforms like BIM 360 and BIM Collaborate in efficient information management.

	-Acknowledgment of challenges, notably proprietary features hindering integration with non-affiliated software, impacting seamless data exchange. Interviewees advocate for open standards, highlighting the importance of Industry Foundation Classes (IFC) for easy information exchange across software tools. -Stress on comprehensive training for stakeholders to effectively utilize CDEs, recognizing the need for enhanced information management skills. -Stakeholder hesitancy to adopt CDEs due to security concerns, especially regarding data privacy and ownership conflicts with cloud-based platforms.
Challenge 4 Interoperability Challenges	- Unanimous agreement among interviewees on challenges in seamless data exchange due to specialists using distinct software with unique file formats. -Difficulty in large-scale projects where enforcing a single software solution proves challenging. - Recognition that employing open file formats resolves interoperability issues, enhancing communication among stakeholders. -Caution about potential drawbacks, emphasizing the importance of selecting the correct version of IFC to mitigate information loss. - IFC file format widely known and utilized by participants for several years, playing a prominent role in facilitating smooth data exchange. - BCF, designed for issue sharing and resolution, receives less recognition among a broader audience, primarily acknowledged by those involved in clash detection.
Challenge 5 Inefficient BIM Usage in the Operations and Maintenance Phase	- Interviewees align with challenges in data emphasis, particularly focusing on design and construction phases, neglecting essential information for operation and maintenance. - Challenges due to future facility managers' limited understanding of effectively utilizing digital building models causing bottlenecks in the process. - Emphasis on the lack of standardization in the Swedish context, where early digitalization occurred without proper standardization, resulting in divergent approaches and practices.

	- The importance of a structured and standardized approach to data collection across the project lifecycle for comprehensive, accessible, and usable data. - Concept of COBie emerges as a notable solution for standardizing and structuring data throughout a project's lifecycle. - There is unfamiliarity with COBie however there is acknowledgement of its potential benefits after understanding its purpose, particularly for operation and maintenance phases.

4.3 Results (Proposed Framework)

4.3.1 Empowering Stakeholders through ISO 19650 Standardization

Considering that the framework will be firmly grounded in the principles and guidelines set forth in the ISO 19650 standard, it is crucial for all stakeholders to gain a comprehensive understanding of this standard. It is equally important for them to comprehend why embracing a common standard is necessary and what benefits it holds for them. This knowledge can serve as a driving force, motivating them to invest the necessary effort in adopting this standard, which may entail learning new software, shifting their mindset, and altering their collaborative practices. Understanding the ISO 19650 standard is fundamental because it forms the bedrock upon which our framework is built.

Managers play a crucial role in facilitating the adoption of these changes among employees. They can achieve this by providing comprehensive training, engaging external experts, offering financial incentives, acting as mentors, maintaining transparent communication, allocating necessary resources, tracking performance, and encouraging feedback. Their leadership and commitment are vital in ensuring a smooth transition to ISO 19650 standards and realizing the associated benefits. In this comprehensive framework, we propose several alternative methods and resources that are readily available to companies seeking the necessary support and guidance for a smooth transition to ISO 19650 standards. These approaches empower companies operating in the construction and built environment sectors to fortify their information management practices and effectively embrace the principles enshrined in ISO 19650:

- Consulting Expertise: One effective avenue is to consider enlisting the services of consulting firms well-versed in ISO 19650 implementation. These firms can offer tailor-made guidance, conduct thorough assessments, and craft implementation strategies that are specifically aligned with a company's unique requirements.

- Academic Collaboration: Collaborating with local universities and academic institutions that offer ISO 19650-related courses or research programs can be highly advantageous. Such partnerships bridge knowledge gaps and provide access to valuable academic resources.
- Peer-to-Peer Learning: Establish connections with other companies that have already successfully integrated ISO 19650 into their operations. Learning from their experiences and adopting their best practices can prove exceptionally beneficial during the transition.
- Online Communities: Active participation in ISO 19650-focused online communities and forums serves as another valuable resource. These platforms facilitate the exchange of insights, experiences, and access to a wealth of valuable resources. A notable example is Building SMART, which not only offers standards and resources but also fosters a global community of professionals and organizations dedicated to open standards and BIM. Being a part of this community can enrich networking opportunities and knowledge sharing among businesses.
- Using the UK BIM Framework as a basic reference: According to feedback from our interviewees, ISO 19650 can be complex and challenging to navigate, which often leads to avoidance. Therefore, in our framework, we recommend utilizing the UK BIM Framework as an initial step towards digital transformation. This approach aims to provide a more accessible entry point and simplify the understanding of ISO standards. The UK BIM Framework is designed to align with the ISO 19650 series' concepts and principles. It serves as a practical guide that has been continuously updated to stay in sync with the evolving ISO 19650 standards. making it a more user-friendly and adaptable resource for the industry.

One important thing to put in mind is that the successful integration of new tools, platforms, and approaches is pivotal for organizations aiming to enhance efficiency and stay competitive. However, the journey towards implementation is often met with resistance from individuals and teams accustomed to existing practices. To navigate this challenge, a strategic approach is required—one that not only introduces novel solutions but also addresses the inherent resistance to change. Our insights are shaped by a comprehensive analysis of data gathered through interviews and an extensive review of the relevant literature. This data-driven approach informs our understanding of the challenges and allows us to tailor our strategies accordingly. In this context, we turn to the ADKAR change model, a proven methodology that focuses on Awareness, Desire, Knowledge, Ability, and Reinforcement. By aligning this model with the presented tools and approaches in our framework, we can systematically overcome resistance, foster a positive environment, and ensure the seamless adoption of transformative changes in information management. Awareness is initiated by clearly defining the goals and benefits of the new tools, communicating how these changes alleviate existing challenges, and providing tangible success stories. Cultivating Desire involves securing leadership support, transparently addressing concerns, and highlighting the positive impact on individual and team performance. The knowledge phase requires identifying specific skills, conducting gap analysis, and providing continuous learning opportunities to ensure proficiency. In building ability, we facilitate collaboration, ensure technological compatibility, and emphasize alignment with industry standards. Finally, reinforcement involves establishing educational programs, sharing success stories, and integrating tools into performance assessments, reinforcing their significance.

4.3.2 Adopting ISO 19650 for documentation and information exchange by utilising Hub Platforms.

After gaining a thorough grasp of ISO and its guiding principles, the pivotal phase revolves around the diligent implementation of ISO protocols with unwavering commitment. This process commences from the project's inception and persists throughout its entire lifecycle. It involves the meticulous utilization of essential documents, including Exchange Information Requirements (EIR) and the Building Information Modelling Execution Plan (BIP), right from the project's initial phases. ISO 19650 places significant emphasis on the necessity of initiating information management practices from the project's very outset. It underscores the importance of aligning all project stakeholders' methodologies and instilling a mindset that seamlessly conforms to ISO's requirements from day one. This strategic alignment is instrumental in ensuring the consistent and unwavering application of information management practices throughout the project's entire lifecycle. In our proposed framework, we highly recommend the utilization of a unified platform or collaboration tool that streamlines the adoption of ISO standards, enabling the clear articulation of requirements and the exchange of documents among stakeholders.

Numerous platforms and tools have emerged as sophisticated cloud-based solutions meticulously designed to elevate the efficiency and compliance of information management within construction projects, placing a significant emphasis on adherence to ISO 19650 standards. Operating as a centralized hub, these innovative solutions empower project stakeholders to collaboratively create, store, oversee, and exchange crucial project documentation. Distinguished by an intuitive and user-friendly interface, these platforms foster a collective commitment to upholding the highest standards of information management. By serving as a cohesive and accessible repository, these tools facilitate seamless communication and coordination among project participants, ensuring a streamlined approach to documentation that aligns seamlessly with ISO 19650 guidelines. These platforms comprise distinct features designed to streamline the information management process in alignment with the ISO 19650 workflow stages. These features include:

- **Scope:** The "Scope" feature helps in defining the scope of the project, which includes specifying what will be included and excluded from the project. It helps in setting clear boundaries and expectations for the project.
- **Contract:** The "Contract" feature assists in managing project contracts and agreements. It allows us to document and track contractual obligations, terms, and conditions, ensuring that all parties adhere to the agreed-upon terms.
- **Schedule:** The "Schedule" feature enables us to create and manage project schedules. This includes defining project milestones, timelines, and task dependencies. It helps ensure that the project progresses according to the planned timeline.
- **Track:** The "Track" feature provides tools to monitor and track the progress of the project. It allows us to compare actual progress with the planned schedule and identify any deviations or delays. This feature helps keep the project on track. In addition, these platforms place a strong emphasis on secure data exchange and sharing among project participants. It offers controlled access to project information, bolstering data security and upholding the principles of confidentiality. The platform's capabilities extend to seamless collaborative workflows, fostering real-time cooperation among project stakeholders throughout the document creation and review processes. A suite of tools, including comments, notifications, and approval workflows, streamlines collaboration and elevates decision-making processes to enhance overall project efficiency.
- **Verify:** The "Verify" feature is used for quality assurance and validation. It helps to confirm that project deliverables meet the specified requirements and quality standards. This is essential for ensuring the project's success and client satisfaction.

At every phase of the ISO 19650 workflow, specific platforms assume a central role in streamlining document management and fostering collaboration among key stakeholders. These tools are indispensable for the creation and management of crucial documents like AIR (Asset Information Requirements), EIR (Exchange Information Requirements), and BEP (BIM Execution Plan), ensuring consistent adherence to ISO 19650 standards across the entire information management process. Informed by the insights gleaned from interviews, our recommendation is to explore the adoption of Plannerly or Morta as valuable platforms for the effective implementation of the ISO frameworks stages including:

Assessment and Invitation to Tender:

During the initial assessment and need phase of the workflow, the appointing party designates an information manager to oversee processes. The "Invitation to Tender" involves compiling comprehensive requirements, including OIR, PIR, and AIR, culminating in the formulation of the Exchange Information Requirements (EIR). Some platforms play a pivotal role in this phase, serving as a secure and controlled platform for the meticulous creation and administration of these documents. Especially the EIR, which is crucial for outlining the client's information prerequisites, providing a robust foundation for subsequent project phases. These platforms ensure secure dissemination of the EIR to contractors and consultants, offering stakeholders access to essential project information while maintaining stringent data security. The platform's integrated approach streamlines the tender process and ensures efficient collaboration among the relevant project teams.

Tender Response and Appointment:

During the tendering process, prospective lead-appointed parties actively engage within the platform ecosystem, utilizing digital environments to respond to inquiries and exchange tender responses. This collaborative workflow facilitates tasks like finalizing pre-appointment BIM Execution Plans (Pre-BEP) and creating comprehensive mobilization plans. The BIM Execution Plan (BEP) is like a road map that shows how to use Building Information Modelling (BIM). It includes important details like which software to use and how to exchange data, making sure that everything is in line with ISO 19650 standards. The integrated nature of the tendering workflow on platforms allows multiple teams to collaborate simultaneously while maintaining privacy, offering a significant improvement in efficiency and collaboration compared to traditional static PDF exchanges.

Subsequently, the appointing party, usually the client, carefully reviews responses, assesses team capabilities, and then appoints one or more lead-appointed parties based on project requirements. Using platforms simplifies contract creation and electronic signing, allowing users to generate a PDF contract and complete the electronic signing process effortlessly with a few clicks.

Mobilization:

In the ISO 19650 workflow, the Lead Appointed Party, chosen by the client, establishes key components such as the Responsibility Matrix Task Information Delivery Plans (TIDPs), and the Master Information Delivery Plan (MIDP) and determines the CDE that will be used. Notably, using the platforms facilitates this process and provides a comprehensive perspective on project essentials. Subsequently, the teams implement the mobilization plan, ensuring systems are in proper working order and gradually producing necessary information deliverables for each documented project stage or milestone.

Information Model Delivery and Project Close-out:

Leveraging a hub platform ensures the systematic delivery of information models aligned with AIR and project requirements. It facilitates ongoing monitoring of progress and adherence to ISO guidelines, playing a pivotal role in project close-out by ensuring comprehensive documentation delivery. This streamlined handover process enhances transparency and accountability.

Eventually, the adoption of these types of platforms provides an effective means to address the multiple challenges outlined in this thesis. This includes mitigating misunderstandings arising from vague requirements, which, in turn, promotes transparent stakeholder communication. These platforms also streamline the documentation and management of these requirements. Furthermore, they offer a solution for handling the issue of overwhelming data in facility management, aligning it with the required level of information.

4.3.3 The Adoption of a Common Data Environment in Construction Projects

In the context of adopting BIM, the integration of a CDE becomes essential. BIM's success hinges on seamless collaboration among diverse project stakeholders, including architects, engineers, contractors, and facility managers. A CDE provides a centralized platform where all project-related data, including models, documents, and information, is stored, managed, and accessed in a controlled and standardized manner. This unified access ensures that all stakeholders are working with the most up-to-date and consistent data, mitigating errors, reducing rework, and enhancing overall project efficiency. Furthermore, a CDE fosters transparency, accountability, and traceability throughout the project's lifecycle, facilitating informed decision-making and enabling teams to meet project objectives efficiently. However, with the seamless integration of a CDE, a transformative shift occurs. All BIM models, along with essential project documents and data, converge into a centralized repository readily accessible to all project stakeholders. This harmonized access ensures that every participant operates with the most up-to-date versions of models and documents, thus mitigating inconsistencies and inaccuracies.

The CDE stands as more than a mere storage space; it embodies a standardized method of managing information. It acts as a collective hub where project data is not just stored but systematically organized and shared among team members. This structured approach guarantees that everyone working on the project can access essential information precisely when they need it. It is essential to emphasize that not every platform with the capability to store and exchange data meets the criteria to be considered a Common Data Environment (CDE). The definition, as per ISO 19650-1, emphasizes its role as the agreed-upon source for project information. Several key assumptions help us recognize a genuine CDE:

- **Agreed Source of Information:** The team must unanimously agree to use the CDE. It serves as the go-to source of information, applicable to both new projects and existing assets.
- **Collecting, Managing, and Disseminating Information:** The CDE acts as a digital repository for various data types, encapsulated as "information

containers." These containers can hold structured data, complete with metadata (such as 3D models and schedules), as well as unstructured data without metadata (like PDFs and photos). CDE not only stores this data but also efficiently organizes and grants access to relevant parties.

- **Managed Process**: CDE operation involves a methodical process. There's a meticulously defined workflow governing how data is collected, stored, and shared within the environment.

The CDE process involves several key stages to manage project information effectively. These stages help maintain order and control during the project lifecycle:

- **Information Container States:** Information containers go through various states during development, each with specific purposes. These states can be managed in several ways, including using metadata, setting up folder structures, or controlling user access within a common database.
- **Work in Progress:** Information containers in this state are actively under development and not accessible to other project team members.
- **Check / Review / Approve Transition:** This is a phase where the container is checked for compliance with project requirements, standards, and procedures by the responsible team.
- **Shared:** Containers in the "Shared" state are visible and accessible to all project members, facilitating coordination and reference, but they are not editable.
- **Review / Authorize Transition:** In this phase, the container is reviewed for compliance. If approved, it moves to the "Published" state. If there are issues, it returns to "Work in Progress" for revisions.
- **Published:** This is where verified and authorized information is available for use by the project team.
- **Archive:** This level serves as a record of all changes made to the information container during the project, which can be helpful in resolving disputes.

Figure 4.1 Illustrate the Common Data environment process based on ISO 19650.

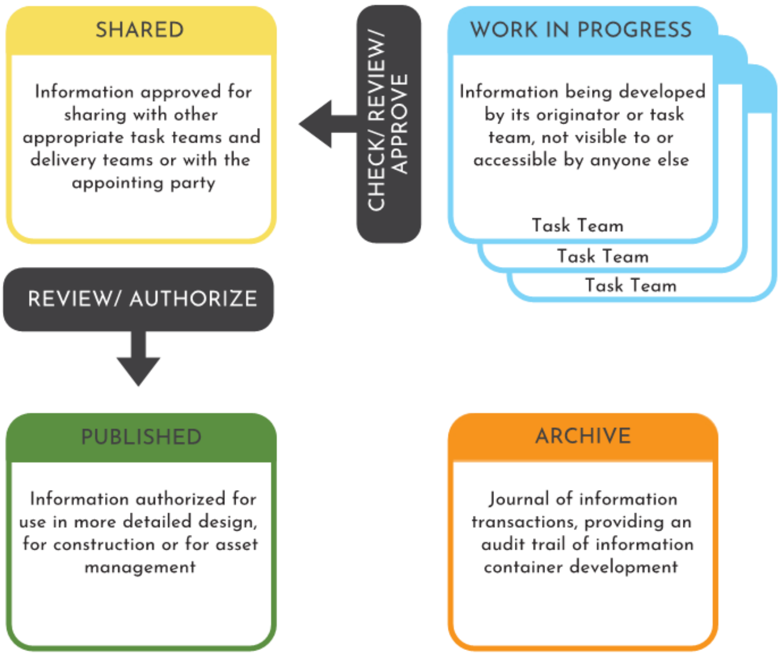


Figure 4.1 Common Data environment process

Metadata Assignment:

Metadata is added to each "information container" to simplify the management process. Metadata provides crucial information about each container, making it easier to categorize and access. ISO 19650-1 clause 12.1 recommends the following metadata assignment to information containers within a CDE:

A revision code:

A status code: Status codes in metadata serve to communicate the state of an information container within the Common Data Environment (CDE). They provide clarity to team members regarding where the information can be utilized and where it cannot. Additionally, these codes offer insights into the stage of development of the information. In the context of British standards, the National Annex provides specific status codes for each stage of the project. These codes help streamline the management and understanding of the information's progress and usability within the CDE. Figure 4.2 presents the status codes for information containers within a CDE.

Code	Description	Revision
Work in progress (WIP)		
S0	Initial status	Preliminary revision and version
Shared (non-contractual)		
S1	Suitable for coordination	Preliminary revision
S2	Suitable for information	Preliminary revision
S3	Suitable for review and comment	Preliminary revision
S4	Suitable for stage approval	Preliminary revision
S5	Withdrawn*	N/A
S6	Suitable for PIM authorization	Preliminary revision
S7	Suitable for AIM authorization	Preliminary revision
Published (contractual)		
A1, An, etc.	Authorized and accepted	Contractual revision
B1, Bn, etc.	Partial sign-off (with comments)	Preliminary revision
Published (for AIM acceptance)		
CR	As constructed record document	Contractual revision

Figure 4.2 Status codes for information containers within a CDE

A classification code: ISO recommends assigning a unified classification to each information container across the entire project. This classification serves to specify the content type within the container, such as its discipline (e.g., architecture, construction, ventilation) or the type of drawing (e.g., model, plan, detail).

Container Name: Information container naming follows this pattern:

The number of the building -level- control area- discipline- system classification code-type of drawing- running number. Figure 4.3 displays a variety of metadata examples assignable within a cloud.

Container Name	Description	Status	Revision	Author	Submittal Date	Container Classification
7001-BBH-ZZ-ZZ-DR-A-00301	First Floor Plan	S3	P04	Joe Blogs	12/11/2017	PM_40_30 : Design information
7001-BBH-ZZ-ZZ-DR-A-00312	West Elevation	A3	C06	Joe Blogs	12/11/2017	PM_40_30 : Design information

Figure 4.3 An example of a range of metadata that can be assigned in a cloud

However, ISO standards and well-defined workflows are central to shaping the CDE process. The use of metadata, status codes, and standardized classifications adds precision and structure to information management. By adhering to these principles, the CDE becomes a linchpin in error reduction, fostering effective collaboration, and ultimately ensuring the smooth and successful execution of construction projects.

4.3.4 Enhance interoperability by using an open format.

The challenge of managing information within construction projects arises from disorganization among project phases, stakeholders, and software applications, which often results in the loss of valuable information. Furthermore, the use of multiple proprietary file formats in various software applications creates obstacles in sharing data and necessitates proficiency in numerous tools. The absence of standardized information structures underscores the necessity for better data management solutions to ensure that information remains accessible and comprehensible throughout the entire lifespan of construction projects. In simpler terms, how we record and store information is crucial because buildings and infrastructure projects can endure for a long time. We can't be sure that future software will be able to read and understand proprietary information about these assets. To address this concern, we suggest the use of open data formats like IFC, BCF, and MVDs.

Embracing an open file format can promote and improve communication and collaboration among all project stakeholders. In essence, open file formats act as a universal language for exchanging data throughout all project stages. By using open file formats, the requirement to adapt and tailor specific software or tools is eliminated. This, in turn, mitigates the issues stemming from the fragmentation between various project phases. Consequently, this promotes effective communication practices, allowing us to apply technology in a suitable manner during the practical execution of the project.

IFC (Industry Foundation Class):

IFC serves as a standardized digital representation of the construction and built asset sectors. It operates as an open, globally recognized standard (ISO 16739-1:2018) and encourages vendor-neutral and versatile functionalities that can operate on various hardware devices, software systems, and interfaces, catering to a multitude of different purposes. Today, IFC is commonly employed for sharing information between various parties in the construction industry. For instance, an architect might furnish the owner with an IFC model depicting a new facility design. The owner can then forward this building model to a contractor to request a bid, and subsequently, the contractor can deliver an as-built model to the owner, complete with specifics about installed equipment and manufacturer details. The advantage of IFC is that it allows all these parties to utilize the same file format, irrespective of whether they use identical software or not. Figure 4.4 Present workflow with IFC model between different disciplines.

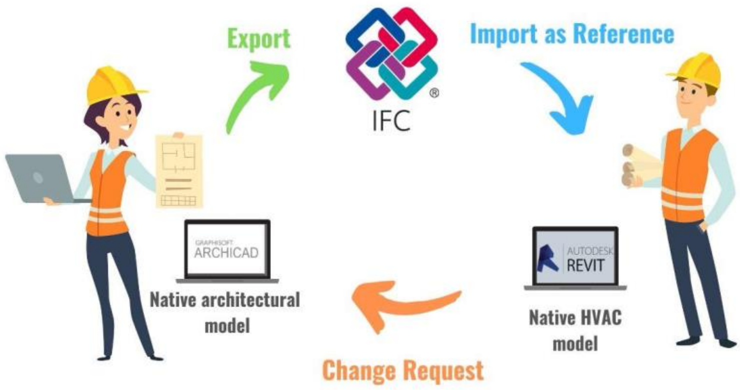


Figure 4.4 Workflow with IFC model between different disciplines

Source: (BIM Corner)
https://bimcorner.com/wpcontent/uploads/2019/12/Workflow.jpg

Over the years, numerous projects have encountered challenges related to IFC 2x3 interoperability, despite most software being IFC 2x3 certified. Errors can occur during the translation between how one software defines an element for export and how another software interprets and displays it. These translation errors are particularly problematic for geometry issues, including viewing openings and cut-outs for doors.

Additionally, there are several challenges linked to the IFC schema, such as the lack of support for parametric geometry, modelling curves and rounded objects as polygons, and limitations in the infrastructural domain. There are also inadequacies in schemas and property sets for distribution systems in the building services domain. These challenges have led to the need for improvements in IFC standards to enhance interoperability and address geometry and schema-related issues.

Subsequently, Building SMART initiated the development of a new version of the format, IFC4, as an extension and improvement of the existing IFC2x3 format. Although initially intended as IFC2x4, the scope of changes made to the schema was significant enough to risk compatibility issues. As a result, it was designated a major release and named IFC4. In 2013, IFC4 was formally integrated into the ISO 16739:2013 standard. This transition aimed to address many of the interoperability challenges faced with IFC 2x3 and improve data exchange and compatibility within the construction and BIM industry.

IFC4 aimed to enhance consistency, reduce file sizes, and improve data exchange in BIM. It introduced significant improvements, including:

- Correction of technical issues.
- Parametric exchange of building elements' attributes.
- Standardized quantity specifications.

- Support for energy calculations and simulations.
- Better language and classification support.
- Enhanced curve and surface Modelling.
- Simplified 4D Modelling and cost data handling.
- Improved BIM to GIS compatibility.
- Expansion to infrastructure domains.
- Clearer technical documentation.
- Deprecation of certain entity types.

However, IFC files play a significant role in maintaining data ownership and content integrity because, when exchanged, they cannot be altered but only viewed. However, in situations where modifications are necessary, BCF files come into play. With BCF files, we can transmit specific portions of the IFC file to relevant parties for issue resolution since BCF files allow for modification.

BCF (BIM Collaboration Format):

BCF, also known as the BIM Collaboration Format, serves as a standardized system for recording and sharing problems, remarks, and notes within a Building Information Modelling (BIM) project. Within BCF files, one can find data related to clashes, discrepancies, errors, or any other issues encountered during the design and construction phases. These files act as a tool for various project participants to cooperate, convey information, and manage issues in an organized manner. Figure 4.5 presents the relationship between IFC and BCF.

In contrast, IFC files are extensive data models designed for the representation of comprehensive BIM data. BCF files, on the other hand, are primarily employed for the purpose of tracking issues and facilitating collaboration by referencing specific elements within an IFC model. Figure 4.5 depicts the relationship between IFC and BCF files in a practical scenario. For instance, consider an architect who utilizes software A to create a building model and save it as an IFC file. Now, an Information Manager or BIM coordinator, using software B, imports this IFC file to review it or perform clash detection. During the review, the information manager identifies an issue within the IFC file that requires modification by the architect to resolve it or prevent clashes with other models. However, it's important to note that the Information Manager cannot directly modify the IFC file since it's not designed for that purpose. Instead, the Information Manager exports the identified issue as a BCF file. This BCF file serves as a structured format for describing the issue, including its location within the model and specific details. The information manager then sends the BCF file to the architect, who can use it as a reference to make the necessary modifications in the original IFC model using software A.

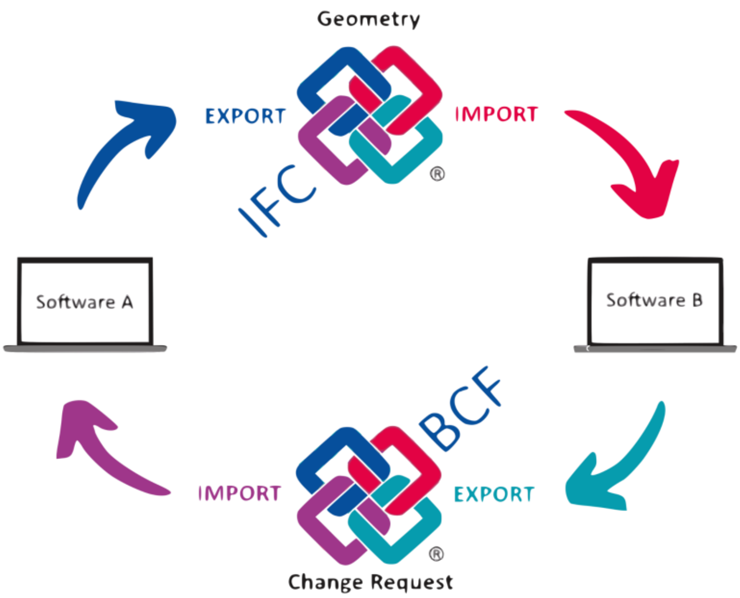


Figure 4.5 Relationship between IFC and BCF.

Source: (Building Smart) https://images.squarespace-cdn.com/content/v1/5f7124a5c793233e04932228/1602919423298-3O9K67T146WX7I0SCZLN/IFC+workflow.

4.3.5 COBie (Construction-Operations Building Information Exchange) and facilities management processes

In our proposed framework, COBie emerges as a valuable solution to tackle construction industry challenges, particularly those related to the need for organized data and smoother information exchange during different project phases. COBie plays a major role by facilitating seamless data transfer across the entire project lifecycle, from design and construction to ongoing operations and maintenance. This function essentially bridges the gaps in communication and collaboration, reducing duplication of efforts and enhancing overall project efficiency.

COBie emerges as a noteworthy integration choice in the design phase due to its vendor-agnostic approach, aligning well with Open BIM principles, and fostering greater interoperability. Instead of inventing new data exchange technologies, COBie leverages established formats such as IFC STEP, XML, and Spreadsheet ML, which are widely compatible, including with software like Microsoft Excel. Its simplicity lies in its user-friendly XML format, accommodating diverse stakeholders and serving as a versatile information source. Importantly, COBie integration offers cost-efficiency by seamlessly extracting data from a BIM model and integrating it into digital asset management systems. This obviates the need for expensive data re-entry, ensuring the continuity of high-quality data for ongoing facility management.

As a result, COBie serves as a standardized and open-source approach for delivering information to facility owners and operators, with a specific focus on FM data. The fundamental objective of COBie is to meticulously organize and structure the data that is generated and accumulated across various stages of a project's development. During the design stage, meticulous planning occurs, shaping how the building will be organized. This phase involves creating designated areas known as "Zones" and "Systems" to streamline management. "Zones" serve to group rooms and floors efficiently, while "Systems" represent the building's essential workings, such as heating or electrical systems.

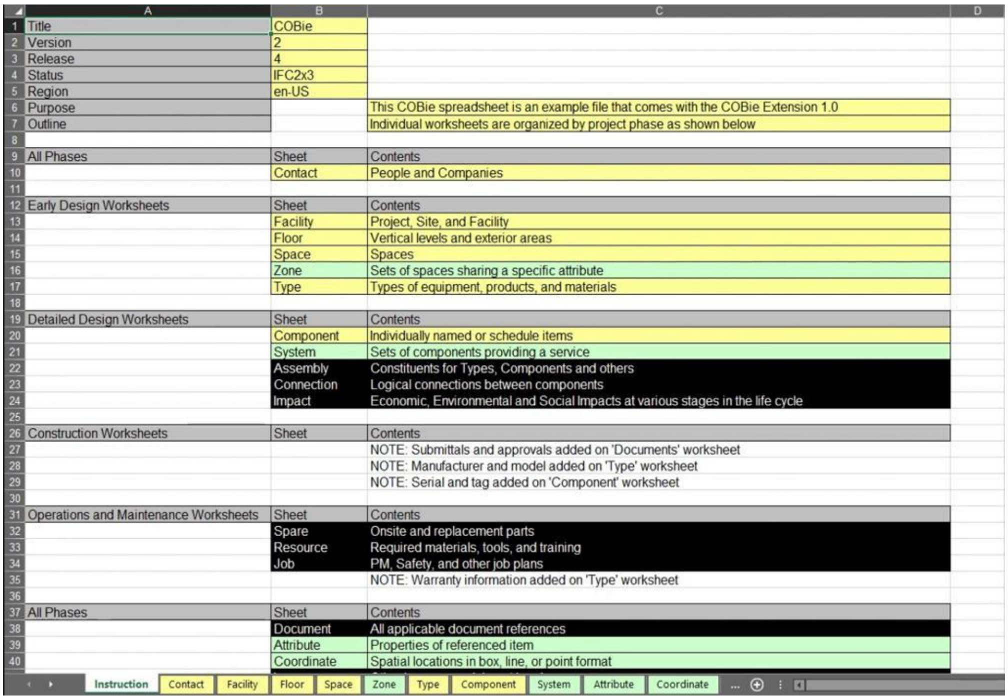
Moving to the construction, precise definitions for all equipment are imperative as the actual structure takes shape. Each piece of equipment is categorized under a specific "Type," detailing its purpose and functionality. Upon the completion of the construction phase, the building is readied for everyday use. This stage heavily relies on 'maintenance tasks' to ensure the seamless operation of the facility. These tasks require the allocation of 'Resources,' such as workers, and the availability of 'Spares,' like replacement parts. When do these parts need regular maintenance, and how to operate or replace these parts to effectively execute maintenance activities.

Across all these project stages, essential "Common Elements" persist consistently from project initiation to completion. These enduring pieces of information serve as a shared foundation that helps everyone involved in the project stay informed and aligned with the project's progress and objectives such as the project timeline, Key Stakeholders, budget and cost information, and Quality Standards.

COBie sheets and their contents

To gain a comprehensive understanding of how to adopt COBie and its practical implications, it is essential to explore COBie sheets and understand their contents. Several worksheets collectively comprise the complete COBie deliverable. It's important to highlight that not all of these worksheets or the columns within them are mandatory. Ultimately, the decision regarding which data is needed and how it should be formatted lies with the building owner. COBie is flexible in this regard, allowing customization to meet specific project or facility management requirements.

- **"Instruction Sheet.":** As shown in figure 4.6, this page provides a valuable overview of the anticipated data content for each subsequent worksheet. Additionally, it includes a legend that explains the meaning of the various colors used in the data columns throughout the sheets, ensuring compliance with the COBie standard.



	A	B	C
1	Title	COBie	
2	Version	2	
3	Release	4	
4	Status	IFC2x3	
5	Region	en-US	
6	Purpose		This COBie spreadsheet is an example file that comes with the COBie Extension 1.0
7	Outline		Individual worksheets are organized by project phase as shown below
8			
9	All Phases	Sheet	Contents
10		Contact	People and Companies
11			
12	Early Design Worksheets	Sheet	Contents
13		Facility	Project, Site, and Facility
14		Floor	Vertical levels and exterior areas
15		Space	Spaces
16		Zone	Sets of spaces sharing a specific attribute
17		Type	Types of equipment, products, and materials
18			
19	Detailed Design Worksheets	Sheet	Contents
20		Component	Individually named or schedule items
21		System	Sets of components providing a service
22		Assembly	Constituents for Types, Components and others
23		Connection	Logical connections between components
24		Impact	Economic, Environmental and Social Impacts at various stages in the life cycle
25			
26	Construction Worksheets	Sheet	Contents
27			NOTE: Submittals and approvals added on 'Documents' worksheet
28			NOTE: Manufacturer and model added on 'Type' worksheet
29			NOTE: Serial and tag added on 'Component' worksheet
30			
31	Operations and Maintenance Worksheets	Sheet	Contents
32		Spare	Onsite and replacement parts
33		Resource	Required materials, tools, and training
34		Job	PM, Safety, and other job plans
35			NOTE: Warranty information added on 'Type' worksheet
36			
37	All Phases	Sheet	Contents
38		Document	All applicable document references
39		Attribute	Properties of referenced item
40		Coordinate	Spatial locations in box, line, or point format

Figure 4.6 Instruction Sheet

The sheets in the spreadsheet can be color-coded to convey specific meanings. Yellow is used to highlight mandatory information, while orange is applied to data referencing another sheet. Purple designates data externally populated by authoring software like Revit. Green-shaded columns are customizable and left to the discretion of the building owner or the facility management team, particularly the building owner. They possess the authority to determine the necessary information for effective building maintenance. White indicates that the data is not required for the current project stage.

- **"Contact Sheet":** As shown in figure 4.7 Contact Sheet serves as a record of all the individuals or entities involved in entering COBIE data for a specific project. It is valuable for tracking and maintaining a record of who contributed to the COBie data, their roles, and how to reach them if further communication or clarification is needed. It helps ensure accountability and transparency throughout the project's lifecycle.

	A	B	C	D	E
1	Email	CreatedBy	CreatedOn	Category	Company
2	bill.east@us.army.mil	bill.east@us.army.mil	2013-11-20T10:13:56	34-55 14 11: Consultant	Engineer Research
3	danielle.r.love@usace.army.mil	danielle.r.love@usace.army.mil	2013-11-20T10:16:13	34-55 14 11: Consultant	USACE
4	mariangelica.carrasquillo@usace.a	mariangelica.carrasquillo@usace.army.mil	2013-11-20T10:18:07	34-55 14 11: Consultant	USACE
5	james.d.mcauley@usace.army.mil	mariangelica.carrasquillo@usace.army.mil	2013-11-20T10:20:12	34-55 14 11: Consultant	USACE
6	info@coleparmer.com	danielle.r.love@usace.army.mil	2013-11-20T10:22:05	34-31 21: Distributor	Cole-Parmer
7	contact@securalldoors.com	danielle.r.love@usace.army.mil	2013-11-20T10:23:38	34-31 11: Manufacturer	Securall
8					
9					
10					

Figure 4.7 Contact Sheet

- **"Facility Sheet":** it provides fundamental information about the building or buildings in the project. In most cases, there will be only one row in this sheet, representing a single facility. However, in larger, multi-facility projects, each building or facility will have its own dedicated row in this sheet to capture specific details and data related to each structure. Figure 4.8 presents the facility Sheet.

	A	B	C	D	E	F	G	H
1	Name	CreatedBy	CreatedOn	Category	ProjectName	SiteName	LinearUnits	AreaUnits
2	PN 0001	danielle.r.love@usace.army	2013-12-30T08:58:02	11-13 24 14: Clinic	Medical-Dental Clinic	Default	Meters	Square Meters
3								
4								

Figure 4.8 Facility Sheet

- **"Floor Sheet":** is a comprehensive breakdown of the various levels within a building, ranging from the basement to the top floor, including any intermediary levels. Each row represents a different floor and contains essential data like its name, elevation, and additional notes. This tab provides insights into the building's layout, facilitating effective management and maintenance. It includes details such as floor identifiers, total floor area, a list of spaces or rooms on each level, descriptions of building components like doors and windows, roof information, and outdoor assets such as landscaping features and utility structures. It's a crucial resource for understanding and overseeing the building's different areas and components. Figure 4.9 presents the floor Sheet.

	A	B	C	D	E	F	G	H	I	J
1	Name	CreatedBy	CreatedOn	Category	ExtSystem	ExtObject	ExtIdentifier	Description	Elevation	Height
2	TOF Footing	danielle.r.love@usace.army.mil	2013-12-30T08:57:58	Floor	Autodesk Revit 2	Autodesk.Revit	fa257128-	TOF Footing	-1	n/a
3	First Floor	danielle.r.love@usace.army.mil	2013-12-30T08:57:58	Floor	Autodesk Revit 2	Autodesk.Revit	fa257128-	First Floor	0	n/a
4	Second Floor	danielle.r.love@usace.army.mil	2013-12-30T08:57:58	Floor	Autodesk Revit 2	Autodesk.Revit	fa257128-	Second Floor	4.57	n/a
5	Roof - Main	danielle.r.love@usace.army.mil	2013-12-30T08:57:58	Roof	Autodesk Revit 2	Autodesk.Revit	fa257128-	Roof - Main	9.25	n/a
6	Site	danielle.r.love@usace.army.mil	2013-12-30T08:57:58	Site	Autodesk Revit 2	Autodesk.Revit	9858d924	Site	0	n/a
7										

Figure 4.9 Floor Sheet

- **"Space Sheet":** serves as a comprehensive resource, offering essential information about each individual room or area within the building. This includes unique identifiers like room numbers or names (e.g., meeting Rooms), the area measurements, and the designated purpose of each space, such as offices, restrooms, kitchens, or storage areas. Additionally, it specifies the zones or sections within the building where each space is located, providing crucial context. Furthermore, the sheet lists any associated building components or equipment found within these spaces, such as furniture, appliances, or fixtures. This detailed documentation is invaluable for effective space management, maintenance, and operational planning.

	C	D	E	F	G	H	I	
	CreatedOn	Category	FloorName	Description	ExtSystem	ExtObject	ExtIdentifier	
il	2013-12-30T08:58:02	13-51 31 11: Waiting Room	First Floor	CENTRAL WAITING	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-85 11 11: Corridor	First Floor	CORRIDOR	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-85 11 11: Corridor	First Floor	CORRIDOR	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-85 11 11: Corridor	First Floor	CORRIDOR	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-85 11 11: Corridor	First Floor	CORRIDOR	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-11 11 31: Reception Space	First Floor	PATIENT ADMIN. RECEPT.	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	RMO ANALYST	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	TRICARE OFFICE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	TRICARE OFFICE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	TRICARE OFFICE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	TRICARE OFFICE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	TRICARE OFFICE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	PHARM. OFFICE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-41 11 14 21: Restroom	First Floor	W. TOILET	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-51 11 21: Break Room	First Floor	LOUNGE	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-75 11 11: Storage Room	First Floor	JAN.	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-41 11 14 21: Restroom	First Floor	M. TOILET	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-41 11 14 21: Restroom	First Floor	STAFF TOILET	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-15 11 34 11: Office	First Floor	SUPER / NCOIC	Autodesk Revit 2	Autodesk.I	3dde7303	r
il	2013-12-30T08:58:02	13-41 41 99: Other Healing Spaces	First Floor	COUNSELING	Autodesk Revit 2	Autodesk.I	3dde7303	r

Figure 4.10 Space Sheet

As indicated in Figure 4.10, the "Floor Name" column is highlighted in orange, signifying that it must serve as a reference to a specific row or floor within the floor worksheet. The "Space Sheet" is focused on furnishing comprehensive details pertaining to individual rooms or specific spaces within a building.

On the other hand, the "Zone Sheet" as presented in figure 4.11 takes a broader perspective by addressing substantial divisions or areas within the building. In this sheet, each row generally represents a zone or section of the building that encompasses multiple rooms or spaces. It includes essential data such as the zone's name or number, its total area, and a concise description of its intended purpose or characteristics.

	Name	CreatedBy	CreatedOn	Category	SpaceNames	ExtSystem	ExtObject	ExtIdentifier	Description
2	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A01	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
3	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A02	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
4	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A03	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
5	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A04	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
6	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A05	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
7	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A06	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
8	Administration	danielle.r.love@usace.army.mil	2014-01-03T06:01:56	Occupancy Zone	1A07	Autodesk Revit 20	RDES Rev	f5787d01-	Administration Department
9	Biomedical	danielle.r.love@usace.army.mil	2014-01-03T06:02:27	Occupancy Zone	1E16	Autodesk Revit 20	RDES Rev	fd286dca-	Biomedical Department
10	Biomedical	danielle.r.love@usace.army.mil	2014-01-03T06:02:27	Occupancy Zone	1E18	Autodesk Revit 20	RDES Rev	fd286dca-	Biomedical Department
11	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1AC1	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
12	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1AC2	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
13	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1AC3	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
14	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1AC4	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
15	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1AC5	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
16	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1AS1	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
17	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1BC1	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
18	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1BC2	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
19	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1BC3	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
20	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1BC4	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
21	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1BS2	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
22	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1CC1	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
23	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1CC2	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
24	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1CC3	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
25	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1CS3	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
26	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC1	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
27	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC2	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
28	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC3	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
29	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC4	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
30	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC5	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
31	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC6	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
32	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC7	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
33	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1DC8	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
34	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1EC1	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
35	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1EC2	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area
36	Circulation	danielle.r.love@usace.army.mil	2014-01-03T06:02:58	Occupancy Zone	1EC3	Autodesk Revit 20	RDES Rev	be3d2742	Circulation Area

Instruction | Contact | Facility | Floor | Space | Zone | Type | Component | System | Attribute | PickLists

Figure 4.11 Zone Sheet

The "Type Tab" as shown in figure 4.12 serves as a repository for standardized information related to a specific asset or component type, applicable universally across all instances within the building. This includes details like manufacturer information, warranty specifications, common attributes, and consistent specifications shared by every asset of that type.

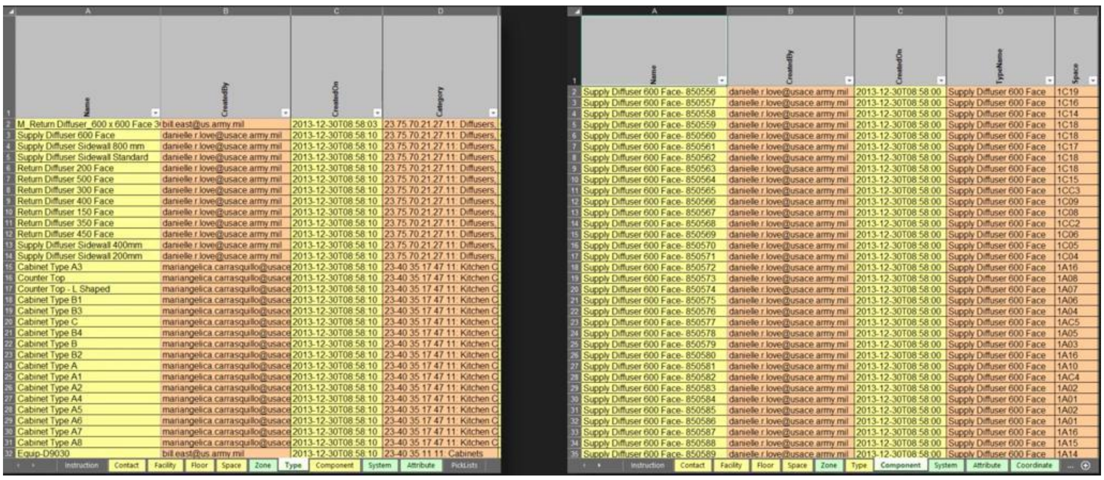


Figure 4.12 Type Tab

The purpose of the "System Tab" is to organize and categorize individual assets from the "Component Tab" into the systems or subsystems they are part of. For example, if there are HVAC components like air handling units, fans, and thermostats, the "System Tab" can establish connections to designate them as components of the HVAC system. This grouping is valuable because it provides insights into how individual assets collectively contribute to larger systems within the building. The key advantage of this approach is that it facilitates system-level analysis, aids in maintenance planning, and simplifies troubleshooting by illustrating the relationships between assets and the systems they form a part of. This hierarchical view ensures that building systems can be managed and maintained more effectively.

Name	CreatedBy	CreatedOn	Category	ComponentNames	ExtSystem	ExtObject	ExtIdentifier	Description
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850556	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850557	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850558	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850559	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850560	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850561	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850562	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850563	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850564	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850565	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850566	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850567	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850568	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850569	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850570	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850571	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850572	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850573	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850574	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850575	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850576	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850577	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850578	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850579	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850580	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850581	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850582	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850584	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850585	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850586	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850587	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850589	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall
HVAC	bill.east@us.army.mil	2013-12-30T08:57:57	21-51 51 16: Air Distribution	Supply Diffuser 600 Face- 850590	Autodesk Revit 20	Autodesk.Revit.DB.Mec	8c770c23-	HVAC System Overall

Instruction Contact Facility Floor Space Zone Type Component System Attribute PickLists

Figure 4.13 System Tab

The "Attribute Tab" shown in figure 4.14 is like a flexible notepad in the COBie workbook. It's where you can jot down any extra information that the building owner wants, especially if it doesn't neatly fit into the standard categories. It's a bit like having a spare page where you can customize and note down unique details about the building. This tab also helps connect this extra information to the right parts of the building by referencing other worksheets and making sure everything is organized correctly. It's all about making sure the owner gets the specific data they need.

	Name	CreatedBy	CreatedOn	Category	SheetName	RowName	Value	Unit	ExtSystem	ExtObject	ExtIdentifier	Description
2	BaseColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924140	n/a
3	BaseMaterial	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924138	n/a
4	CeilingColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924160	n/a
5	CeilingMaterial	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924158	n/a
6	FloorColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924136	n/a
7	FloorMaterial	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924134	n/a
8	Name	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	CENTRAL WAITING	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	-1006900	n/a
9	Number	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	1AC1	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	-1006901	n/a
10	WallColor-East	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924148	n/a
11	WallColor-North	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924144	n/a
12	WallColor-South	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924152	n/a
13	WallColor-West	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924156	n/a
14	WallMaterial-East	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924146	n/a
15	WallMaterial-North	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924142	n/a
16	WallMaterial-South	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924150	n/a
17	WallMaterial-West	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC1	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924154	n/a
18	BaseColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924140	n/a
19	BaseMaterial	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924138	n/a
20	CeilingColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924160	n/a
21	CeilingMaterial	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924158	n/a
22	FloorColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924136	n/a
23	FloorMaterial	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924134	n/a
24	Name	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	CORRIDOR	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	-1006900	n/a
25	Number	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	1AC2	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	-1006901	n/a
26	WallColor-East	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924148	n/a
27	WallColor-North	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924144	n/a
28	WallColor-South	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924152	n/a
29	WallColor-West	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924156	n/a
30	WallMaterial-East	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924146	n/a
31	WallMaterial-North	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924142	n/a
32	WallMaterial-South	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924150	n/a
33	WallMaterial-West	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC2	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924154	n/a
34	BaseColor	danielle.r.love@usace.arm	2013-12-30T08:58:02	Approved	Space	1AC3	n/a	n/a	Autodesk Revit 20	Autodesk.Revit.DB.Param	924140	n/a

Figure 4.14 Attribute Tab

In the process of crafting COBie sheets, a diverse array of software tools plays a pivotal role, each serving distinct purposes. Notably, widely embraced BIM authoring software, such as Autodesk Revit, Bentley Systems' AECO sim, and Graph iSOFT's ArchiCAD, emerge as prominent players in the creation of COBie-compliant data. These software solutions are equipped with built-in COBie functionality, allowing for the seamless generation of compliant data directly within BIM models. Consequently, they find extensive application during the design and construction phases of building projects. For greater adaptability and customization, spreadsheet software such as Microsoft Excel and Google Sheets is frequently enlisted.

As buildings transition into the operational phase of their life cycles, FM software solutions become instrumental. Notable examples encompass IBM TRIRIGA and ARCHIBUS, which often incorporate COBie capabilities into their frameworks. This integration facilitates efficient data management, ensuring the seamless operation and maintenance of buildings.

The Flowchart

In the world of managing information, a solid framework is the guiding force that paves the way from conception to realization. Our proposed structured framework provides a theoretical scaffold, integrating principles and methodologies to guide organizations in the systematic handling and utilization of data. To further simplify and illustrate the intricate process, we've distilled this framework into a user-friendly flowchart. This roadmap acts as a bridge, seamlessly connecting the strategic framework with practical, actionable steps.

Furthermore, it offers a tangible depiction of the strategic concepts outlined in the framework, providing companies with a clear and academically grounded roadmap for the successful implementation of Information Management practices.
Figure 4.15 presents the flowchart for our proposed framework.

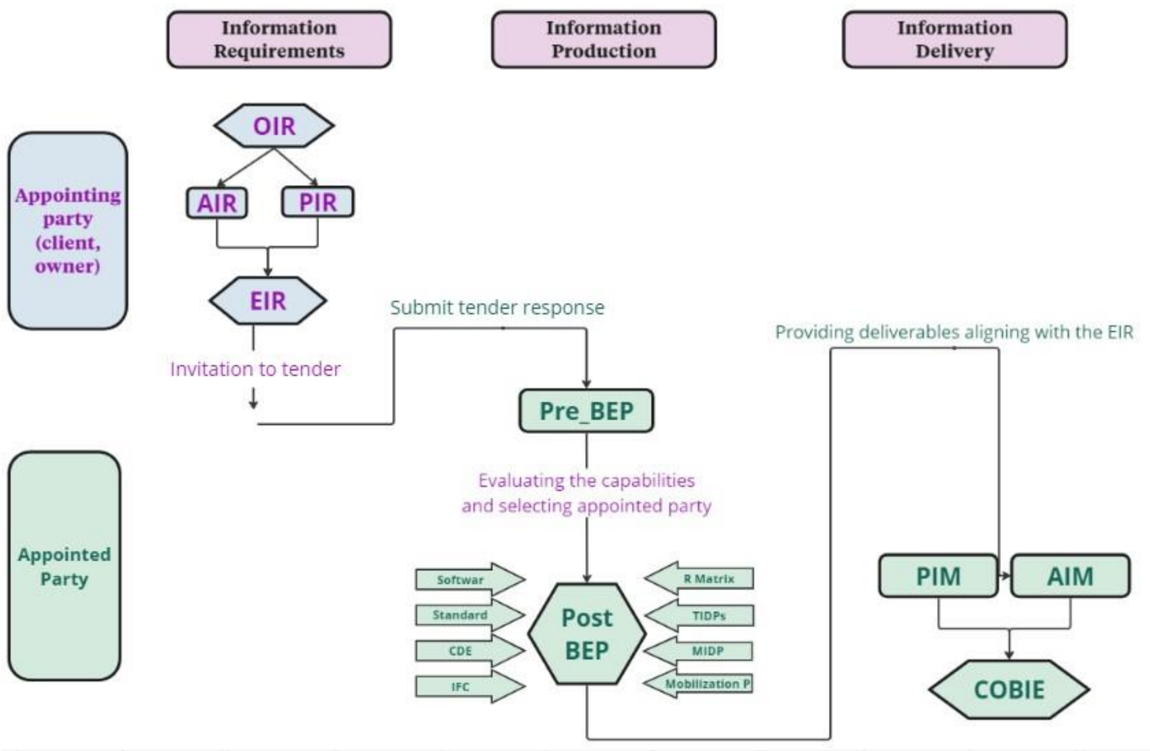


Figure 4.15 Framework Flowchart

In the initial stage of the workflow, commonly referred to as the assessment and needs phase, the appointing party, typically the client, compiles a comprehensive set of requirements to guide potential bidders. These requirements encompass Organizational Information Requirements (OIR), Project Information Requirements (PIR), and Asset Information Requirements (AIR). Collectively, these client-driven requisites culminate in the formulation of the appointing party's Exchange Information Requirements (EIR).

The EIR documents serve as the foundation for the Invitation to Tender, a document of paramount importance that meticulously delineates the client's exacting information prerequisites. This establishes a robust foundational framework guiding subsequent project phases. The EIR is disseminated to potential contractors and consultants during the tendering process.

Prospective appointed parties engage in a collaborative workflow, providing responses to inquiries and exchanging tender responses. This process facilitates the completion of tasks such as finalizing pre-BIM Execution Plans (Pre-BEP) and developing comprehensive mobilization plans. The BIM Execution Plan (BEP) serves as a strategic blueprint for utilizing Building Information Modelling (BIM) within the project, encompassing critical aspects such as software selections, collaborative methodologies, and data exchange standards.

Following this, the appointing party meticulously scrutinizes responses, assessing the capabilities and competencies exhibited by participating teams. Subsequently, one or more lead-appointed parties are selected based on project requirements.

After the selection of the Lead Appointed Party, their core responsibilities include establishing critical components as a post-BEP. This involves creating the Responsibility Matrix, Task Information Delivery Plans (TIDPs), and the Master Information Delivery Plan (MIDP).

Upon finalizing all BIM and information management appointments/contracts, project teams gain clarity on their respective deliverables. The lead-appointed party assumes the pivotal role of mobilizing a dedicated team and conducting comprehensive system tests, including establishing the Common Data Environment (CDE).

Following this, teams implement the mobilization plan, ensuring systems are in proper working order and gradually producing the necessary information deliverables for each documented project stage or milestone.

5 Chapter Five: Conclusion and Recommendation

5.1 Conclusion

The purpose of this study was to address the ongoing issues the construction industry faces, particularly in the area of information management. The escalating costs, conflicts among stakeholders, and customer dissatisfaction are often attributed to ineffective information management practices. The study aimed to investigate common challenges hindering efficient information management in construction projects, design a robust framework to address these challenges, and promote teamwork to facilitate effective information management throughout the project lifecycle. The research methodology involved a comprehensive literature review and interviews with key stakeholders in the construction industry. The literature review encompassed academic papers, reports, and pertinent industry literature, ensuring a reliable and scholarly foundation for the investigation. The interviews involved professionals from construction companies, experts in information management, and relevant project stakeholders, providing a diverse representation of expertise within the industry.

The main findings of the study revealed that the primary challenges in information management within the construction sector included incomplete, inaccurate, or poorly defined requirements leading to suboptimal decision-making, operational inefficiencies, and a reduction in the quality of facility operation and maintenance. The study also identified the need for a structured approach to addressing challenges and improving information management practices across stakeholders. The proposed framework is designed to establish a robust approach for efficient information management in the construction industry, aligning closely with the real-world needs and challenges identified during the interview process. It is rooted in the principles and guidelines outlined in the ISO 19650 standard and provides solutions and recommended tools to facilitate the seamless implementation of the standard. Stakeholders in the construction industry, including construction companies, professionals in information management, and relevant project stakeholders, can benefit from applying this framework to enhance project outcomes, support successful facility operations, and reduce life cycle expenses.

The proposed framework for information management in the construction industry encompasses several key steps to address challenges and promote effective practices. These steps include:

1. The framework emphasizes the importance of stakeholders gaining a comprehensive understanding of the ISO 19650 standard and the benefits it holds for them. This knowledge serves as a driving force to motivate stakeholders to invest the necessary effort in adopting this standard, which may entail learning new software, shifting mindsets, and altering collaborative practices.

2. The use of hub platforms to streamline workflows and document management in alignment with the ISO 19650 standard. These platforms can facilitate the efficient exchange and management of information, promoting transparency and collaboration among stakeholders.

3. The adoption of a CDE to ensure that all project stakeholders have access to consistent and up-to-date information. A CDE can serve as a centralized platform for managing project data and promoting effective communication and collaboration.

4. The importance of using open formats to enhance interoperability between different systems and software used in construction projects. This approach can facilitate the seamless exchange of information and data between stakeholders, promoting efficiency and reducing the risk of data loss or misinterpretation.

5. The potential benefits of COBie for standardizing and structuring data throughout a project's lifecycle, particularly for operation and maintenance phases. The framework encourages stakeholders to understand its purpose and potential benefits, promoting its adoption as a valuable tool for information management in construction projects.

5.2 Recommendation

In consideration of the study's established objectives and acknowledged limitations, this study recommends avenues for future research:

1. Future research efforts may benefit from broadening the geographic scope beyond Sweden. This expansion aims to delve into challenges and solutions related to information management in construction projects across diverse countries. By adopting a more comprehensive international perspective, the study can contribute to the identification of global best practices in this domain.

2. A promising area for future investigation involves exploring the impact of emerging technologies, such as artificial intelligence and machine learning, on information management in the construction industry. Gaining insights into the potential benefits and challenges associated with these technologies is crucial for informing the development of future frameworks and guidelines in the field.

3. To further advance understanding, future research should focus on the practical implementation and effectiveness of the proposed framework in real-world construction projects. This could entail conducting case studies or surveys among construction professionals to evaluate the framework's practicality, usability, and its overall impact on project outcomes.

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