EVALUATING THE EFFECTS OF BUILDING HANDBOVER INFORMATION QUALITY ON ASSET MANAGEMENT
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Introduction

Effective management of complex-built assets, such as commercial buildings, relies heavily on quality handover information. Reliable handover information plays a crucial role in providing guidance and instructions for routine maintenance and operational support. Credible handover information is indispensable for developing short- and long-term asset management goals as a substantial portion of a building’s total investment, up to 85%, occurs during the post-construction phase (Thabet and Lucas, 2017). Recent catastrophic building failures, including the Grenfell Tower fire in London, UK, have underscored the importance of reliable and trustworthy building handover information. These incidents have brought attention to the urgent and critical need for credible and valid building handover information. Investigations into these failures have exposed the pervasive shortcomings of the existing building information management practice in the Architecture, Engineering, and Construction (AEC) industry, resulting in inaccurate, incomplete, and outdated information that is ineffective for use (Hackitt, 2018). Moreover, the findings of these investigations emphasise that substandard handover information can pose significant safety risks for building occupants (UK, 2022).

Handover information encompasses essential details about building projects, delivered in graphical and non- graphical formats. Graphical information typically consists of as-built drawings, while non-graphical information includes product details, operation and maintenance manuals, warranty certificates and other relevant information (Kassem et al., 2015). Recognised as vital for supporting post-construction activities, the specific requirements for handover information remain a subject of debate. Previous studies have proposed diverse approaches to identify building handover information requirements based on organisational needs, building types, and practical necessities for operational needs (Rotimi et al., 2015; Zhu et al., 2021). However, limited research in this area resulted in inconclusive findings and contentious debates surrounding quality requirements. Furthermore, the lack of a clear understanding of the projected use of handover information poses additional challenges, particularly regarding the potential consequences of using poor-quality handover information for managing buildings.

The recent proliferation of Building Information Modelling (BIM) adoption in the Architecture, Engineering and Construction (AEC) industry presents an opportunity to deliver a large volume of reliable handover information. BIM has enhanced the data exchange process during the project delivery phase, resulting in a quality collection of reliable information. However, recent studies revealed shortcomings in design quality and challenges in seamlessly transitioning handover information from the project delivery to the post-construction phases (Sadeghi et al., 2019). While new projects can take advantage of BIM’s capability to generate a wealth of project information in digital formats, many asset owners still oversee buildings constructed predating digital solutions such as AutoCAD (Parn et al., 2016). A significant number of these buildings continue to be in service, presenting difficulties and limitations in managing the legacy information (Roberts et al., 2018). Furthermore, recent global incidents of building failures have demonstrated that the quality of handover information often degrades over time with the implementation of technological solutions (Hackitt, 2018; Zhu et al., 2021).

Therefore, this research is targeted to answer the following research questions by conducting an empirical investigation to enhance our understanding of the effects of quality handover information on asset management, the root causes of quality deterioration, and the role of Cloud-based BIM in addressing quality issues:

1. How does the quality of building handover information on asset management activities?
2. Why does the quality of handover information deteriorate during the post-construction phase?
3. Based on the findings of RQ #2, how can the application of cloud-based BIM address information quality dilemmas?

This study adopts a case study with nine organisations managing portfolios of commercial buildings in the US, UK, Northern Ireland, Germany, and Ireland. Asset management professionals who regularly rely on handover information from each organisation participated in semi-structured interviews to share their perspectives and lived experiences on the underlying causes of the deterioration of handover information. Following the guidance of qualitative advocates, this research conducted a qualitative thematic analysis with the interviews. One of the Root Cause Analysis
techniques, namely Fishbone Diagrams, was used to categorise the underlying reasons for the quality decline. With the root cause analysis results, this study conducted supplemental interviews with technological solution providers in the AEC industry to explore the feasibility of implementing cloud-based BIM applications as a potential solution to address the quality challenges identified.

**Methodology**
This research employs a case study strategy to investigate the key events and activities that can lead to a deterioration in the quality of handover information. The case study methodology is a valuable empirical inquiry that enables researchers to explore a topic or phenomenon in a real-life setting (Yin, 2018). Additionally, conducting a multi-case comparative study allows for the identification of similarities and differences across cases. Therefore, a multi-case approach is adopted to probe how the quality of handover information affects the outcomes of asset management activities and why the handover information deteriorates during the post-construction phase. The underlying reasons for the quality deterioration in each case represent one unit of analysis. Based on the findings of possible reasons for the quality deterioration, this study conducts additional interviews with stakeholders of the technological solution providers to understand how cloud-based BIM can be leveraged to address the quality dilemmas.

The study consisted of three distinct phases. The first phase involved conducting a comprehensive literature review to explore previous studies related to the quality of delivering handover information during the project delivery phase and the management of handover information in the post-construction phase. The literature review aimed to identify existing frameworks, methodologies, information management practices, methods of controlling quality, and relevant tools and techniques employed in previous research. The second phase consists of a multi-case study including semi-structured interviews, qualitative thematic analysis, and root cause analysis. In the third phase, this study conducts supplemental interviews with participants from the technological solution providers for the AEC industry.

**Case selection and participant recruitment**
A purposive sampling strategy was used to select cases and participants in this study carefully. This approach was chosen because it allows for an in-depth investigation using small sample sizes, ensuring that the selected cases and participants are best suited to address the research questions (Patton, 1999; Creswell, 2014). By deliberately selecting cases and participants based on specific criteria, we aimed to maximise the relevance and richness of the data collected, ultimately enhancing the depth and quality of the findings. Before selecting the cases, we developed case selection criteria based on the guidelines of Miles et al. (2018).

This study selected nine cases that manage multiple commercial buildings under different use to support each organisation’s business operations. There is no ideal number of cases, and debate about different points of view in determining the right number of cases continues. From this perspective, we adopted the practice used by case study scholars of stopping data collection once theoretical saturation is reached, meaning gathering additional data will not contribute any new insights (Creswell, 2014). After conducting nine cases, this study has reached its saturation point.

A similar approach was used to recruit participants from the technological solution providers for the AEC industry. The saturation point was reached after interviewing 12 participants from the technological solution providers.

**Data collection**
To conduct successful research, it is crucial to ask the right questions and choose effective methods to answer them (Edmondson and Mcmanus, 2007). This study conducted semi-structured interviews to gain insights into the quality deterioration of handover information from participants’ perspectives and first-hand experiences. This approach was deemed appropriate because interviews are ‘one of the most important sources of case study evidence’ (Yin, 2018, p. 118). Semi-structured interviews allow participants to share their experiences through guided conversation, enabling them to delve deeper into their perspectives and articulate their views in organic and authentic ways.

Subsequently, this research generated a list of predefined interview questions into five categories: (1) classifications of handover information to support particular asset management processes, (2) the existing quality of handover information, (3) examples of poor quality of information, (4) probable reasons for the quality deterioration, and (5) possible deficiencies in managing handover information. The interviews consisted of open-ended questions, enabling the researcher to explore the specific events and activities that led to a decline in the quality of handover information.

During the interviews, the participants discussed the different types of handover information required and their quality. They shared examples of low-quality information and discussed possible reasons that may have caused the inferior quality. The participants drew from their professional experiences to provide relevant examples but could decline to answer any sensitive questions. The interviews lasted for about an hour and
were recorded and transcribed with the participants’ consent. Further, this study included the validation process to ensure the accuracy of the participant’s input. This process was conducted in accordance with the research guidelines outlined by Saunders et al. (2019).

**Data analysis**

In analysing the interview data, this study followed steps for qualitative thematic analysis recommended by (Gioia et al., 2013). Initially, the raw interview data were carefully coded to identify emerging concepts, which are known as 1st order concepts. Repetitive concepts were eliminated, and categories were combined to reduce the number of codes, forming 2nd order themes. Before performing a complete analysis, we adjusted the codes to ensure the objectivity of the collected data, enhancing the reliability and validity of the final results (Weber, 1990). The researcher used the qualitative data analysis software NVivo12 to facilitate the coding process and maintain a chain of evidence, transparency, and consistency in the multiple coding process (Miles et al., 2018; Yin, 2018).

Using the results obtained from the coding process, a comprehensive case analysis description for each case was generated, highlighting the key findings. Furthermore, a root cause analysis was performed for each case by constructing a causal and effect diagram, commonly known as a fishbone or Ishikawa diagram. This diagram allowed us to visually represent the various factors contributing to the quality deterioration of handover information. Subsequently, a cross-case analysis was performed to identify similarities and differences in the underlying reasons for the decline in the quality of handover information. This analysis provided valuable insights into the factors influencing the handover process across multiple cases. With this analysis, additional interviews were conducted to provide the perspectives of technology solution providers in leveraging cloud-based BIM to address the quality challenges for managing handover information.

This study effectively identified and compared emergent themes from each case by implementing a systematic thematic process, leading to meaningful insights. Furthermore, the utilisation of fishbone diagrams allowed us to gain a comprehensive understanding of the root causes behind the quality deterioration while also organising the various reasons into distinct discussion topics. This approach enabled a more focused and structured analysis of the factors influencing the decline in quality. The results of the participant’s interviews and the viewpoint of technology solution providers provided practical implications for leveraging emerging technologies to address quality issues.

**Findings**

**RQ #1: How does the quality of building handover information on asset management activities?**

The results indicate that as-built drawings, product data, and owner’s manuals are predominately used for complying with a wide range of statutory obligations related to operating commercial buildings. These obligations encompass regular inspections of electrical, fire, life and safety systems, HVAC, gas-fired heating equipment and water quality. To meet the legal duties of operating buildings, the quality dimensions of ‘Accuracy’, ‘Completeness’, and ‘Timeliness’ of as-built drawings and equipment information are required. Moreover, handover information is instrumental in contracting and procuring external service providers for maintenance and inspection services. A collection of site and floor plans are specifically employed for effective management of physical space, ensuring compliance with internal organisational requirements. In supporting physical space management, complete sets of accurately updated handover information are necessary when managing multiple buildings because this ensures the safety of building users while safeguarding the liabilities of asset owners. Lastly, handover information plays an indispensable role in establishing strategic planning of capital investment and recurring operating expenditures. By leveraging the insights provided by handover information, asset owners can make informed decisions regarding the allocation of resources, optimising building performance, and achieving long-term financial goals. These findings underscore the multifaceted significance of handover information and its quality preferences in meeting the desired outcomes of legal obligations, managing physical space, and facilitating informed decision-making for operational and strategic purposes in the context of commercial building management.

**RQ #2: Why does the quality of handover information deteriorate during the post-construction phase?**

The results of the thematic analysis and the root cause analysis provide substantial evidence that highlights the underlying causes contributing to the decline in the quality of handover information. The root cause analysis based on the findings across cases indicates the following factors significantly cause the quality deterioration of handover information:

- Inconsistent handover information management processes, particularly for minor projects, face significant challenges due to the absence of well-defined protocols for managing all aspects of handover information.
- Rapid technological advancements in the Architectural, Engineering, and Construction (AEC) industry have introduced challenges in
effectively managing both legacy and digital formats, mainly for as-built drawings.
• Data loss during file conversion from one format to the other and data loss over time.
• External factors such as evolving legislation updating the information requirements and the absence of appropriate tools for managing legacy handover information.
• Human factors, including employee competency and human errors and omissions during information handling.
• Organisational issues such as misunderstanding of the role of handover information in the building management among leadership and the lack of leadership support in supplementing dedicated resources for managing handover information.

RQ #3: Based on the findings of RQ #2, how can the application of cloud-based BIM address information quality dilemmas?

Some of the initial findings are:
• The adoption of technological solutions does not inherently establish an effective workflow for managing handover information.
• The AEC industry lacks adequate solutions for handling handover information that predates the AutoCAD era.
• Automatic handover information for as-built drawings and non-graphical information transfer to various designated asset information systems is not available.
• The use of low-cost AI can assist in transferring non-graphical information to a tabular format, but there is a risk of altered scale when scanning drawings.
• Point cloud scanning establishes architectural spatial plans only.
• Cloud-based BIM has the potential to mitigate information loss, but without regular updates, the information can become outdated or stale.

Work to be completed
Based on the findings of RQ #2, I intended to conduct additional interviews with software engineers involved in the development of digital solutions for the AEC industry. These interviews will be conducted during my secondment at Trimble Solutions in Finland. To gain their perspectives on emerging technologies to address information quality issues during my secondment at Trimble Solutions in Finland. The objective is to gather insights and perspectives from these professionals regarding emerging technologies aimed at addressing the issues related to handover information quality.

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References


