An Empirical Investigation on the Use of Building Handover Information and its Quality Requirements for Commercial Building Management

Abstract

Purpose: Global building failures, such as the Grenfell Tower fire in London, UK, emphasised the need for trustworthy building handover information for safety. However, a notable gap remains in understanding how reliable handover information can ensure the safety of occupants. This study investigates the use and the essential quality of handover information to understand the effects of the quality of information on the management of commercial buildings.

Design/methodology/approach: Ninety-four participants from nine organisations who regularly use handover information to manage multiple commercial buildings participated in the semi-structured interviews. Qualitative thematic coding using interview transcripts was performed to identify the utilisation of handover information and its quality requirements.

Findings: The study reveals that as-built drawings and product information are predominately used to fulfil statutory obligations, comply with the organisation's internal policies, evaluate asset valuation, and make informed decisions about capital investment and operating expenses. The quality dimensions of 'Accuracy', 'Timeliness', and 'Completeness' are preferred in combination to achieve desired outcomes.

Research limitations/implications: This study focused on using handover information in the management of commercial buildings. However, its results can offer valuable perspectives for improving its application across various sectors in the built environment.

Practical implications: The findings affirm the need for quality handover information for safety, compliance, and efficient management in commercial buildings.

Original/value: This research significantly contributes to the current knowledge of handover information in the building sector. Given the study findings, building owners are equipped to define specific handover information requirements and quality requisites.

Keywords: Building handover information, information quality dimensions, quality deterioration, asset management, commercial buildings

1. Introduction

Various catastrophic building failures, including the Grenfell Tower fire in London, UK, have brought attention to the urgent and critical need for reliable and trustworthy building handover information in building management. Investigations into these failures have emphasised the importance of maintaining quality handover information to ensure occupants' safety (UK, 2022). In response, certain countries like the UK have enacted legislation requiring asset owners to uphold credible and valid handover information throughout the post-construction phase (Hackitt, 2018). In this context, the events surrounding the management of handover information have significantly altered the general understanding of its role in building management. While handover information has traditionally been utilised for routine maintenance and operational support, its intended use beyond these areas remains unclear, and a lack of clarity hampers the realisation of the full value and potential of managing handover information. To fill this knowledge gap, it is essential to clarify the purpose and potential applications of handover information and its quality requirements to manage buildings comprehensively.

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; Chang *et al.*, 2022). The quality and specific requirements for handover information, particularly for its intended use, remain debated. 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, research gaps on the application of handover information have resulted in inconclusive findings. High-quality handover information is essential to minimise the financial consequences of poor quality, but contentious debates and lack of clarity in its use, especially in Building Information Modelling (BIM)-based projects, present ongoing challenges.

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 improves data exchange in the project delivery phase, resulting in a quality collection of dependable information. However, the widely

acclaimed benefits of BIM depend on identifying the information requirements to optimise post-construction support (Parn *et al*., 2016) BIM can produce extensive digital project information at an unprecedented rate. Yet, unclear information requirements may lead asset owners to inefficiently navigate and potentially lose valuable information (Munir et al., 2019). BIM-based projects often provide handover information in unconventional formats, but their core information requirements remain largely unchanged. Previous studies indicate that asset owners have a 'catch-all' approach due to a lack of specific information requirements for building management processes (Becerik-Gerber *et al.*, 2012; P. A. Zadeh *et al.*, 2017; Munir *et al.*, 2020)

This research, therefore, aims to address the following research objectives by conducting an empirical investigation to enhance the understanding of the role of handover information:

1. Identify the use of building handover information to support the management of commercial buildings and
2. Identify key information quality attributes that align with the desired outcomes of commercial building management.

Ninety-four participants from nine organisations managing portfolios of commercial buildings participated in semi-structured interviews. This approach is strategically chosen to gather evidence-based insights into the use of handover information and its quality requirements from the user's perspective, which is essential for yielding the desired outcomes.

This paper is structured as follows: Section 2 reviews relevant studies on handover information requirements and quality in supporting building management. Section 3 outlines the participant selection, data collection and analysis. Section 4 presents the findings derived from interviews. Section 5 discusses the significance of these findings. Finally, the paper concludes with a summary of key takeaways, theoretical and practical contributions, limitations of the study, and suggested paths for future research.

2. Literature Review

This section presents an overview of the literature review, focusing on the use of handover information and its quality requirements in commercial building operations. A narrative approach was adopted to synthesise key literature pertinent to this study selectively (Greenhalgh *et al*., 2018). A comprehensive literature search was conducted using Scopus and Web of Science databases. Additionally, relevant industry publications were consulted, including International Organization Standards (ISO) 8000 series: Data Quality, ISO 19650: Building Information

Modelling, and ISO 55000: Asset Management. This study also referenced the six primary dimensions for data quality assessment established by Data Management (DAMA), UK.

2.1. The management of commercial buildings in a built environment

The management of complex-built assets such as commercial buildings involves a comprehensive approach beyond routine maintenance and daily operational support. ISO 55000 outlines asset management guiding principles, value realisation, business alignment, leadership, quality assurance and compliance with legislative requirements and organisational policies or sector regulations (The International Organization for Standardization, 2014). External compliance is key for safety and requires following specific requirements and practices, including periodic mandated inspections and testing of various assets within a building, such as electrical fixed wiring and equipment integrity inspections (The Institute of Asset Management, 2015). However, understanding the specific statutory compliance requirements can be challenging, complicated by limited and handover information, which can vary by location.

2.2. Handover information and its requirements

Appendix 1 illustrates various handover information categories for a typical commercial building project, though its effectiveness remains to be conclusively determined. Recently, ISO 19650 Part 3 outlined the practical applications of handover information in the post-construction phase, underscoring its supportive role (International Organization for Standardization, 2020). Additionally, Liu *et al.* (1994) highlighted the significance of floor plans and design specifications in operational support, the criticality of spatial information related to door locations and the identification of rooms and equipment. Becerik-Gerber *et al.* (2012) emphasised the need for non-geometric information, such as manufacturing data, operational instruction, maintenance specifications, and warranty information. Mayo and Issa (2016) noted the high value of key product information related to fire, life and safety and HVAC systems. Moreover, identifying handover information requirements involves considering factors such as organisational needs, operational requirements, contractual obligations, building types, and asset groups (East *et al*., 2013; Cavka *et al.*, 2015; Farghaly *et al.*, 2018; Pishdad-Bozorgi *et al.*, 2018; Munir *et al.*, 2020). However, the integration of regulatory perspectives into these requirements remains unaddressed.

2.3. Information quality

Information quality is defined as its ability to meet end-user expectations and needs (Wang and Strong, 1996; English, 1999; DAMA International, 2017). The widely accepted definition implies that users determine quality attributes based on the information's intended use (Wang and Strong, 1996; Strong, Lee and Wang, 1997; Pringle *et al*., 2002). Information commonly refers to processed data; different information can be produced using the same data – the raw material of information – to fit a particular use (Mingers, 1996; DAMA International, 2017). This dynamic nature means it can become outdated yet remain reusable without losing its value (Eaton and Bawden, 1991; Redman, 1995). Managing information involves efficient and effective accessing, processing, and using information efficiently and effectively to meet the organisational objectives throughout the information lifecycle, including creation, acquisition, organisation, storage, distribution, and use (DAMA International, 2017).

Given the characteristics of information, various approaches developed frameworks for defining quality attributes due to the established correlation between information quality and business performance outcomes (Wang and Strong, 1996; English, 1999; DAMA International, 2017; He *et al*., 2022). Wang and Strong (1996) proposed four categories of information quality and relevant dimensions from the end user's perspective: intrinsic (accuracy and objectivity), contextual (relevancy, timeliness, and completeness), representational (interpretability and consistency), and accessibility (access security). English (1999) classified the characteristics into two broad categories: (1) Inherent and (2) Pragmatic aspects. Inherent characteristics are definitional conformity, complete values, validity, accuracy, precision, non-duplication, equivalent redundant or distributed data, and concurrent redundant or distributed data. Pragmatic characteristics include the presentation of data quality that meets the user's needs, such as accessibility, timeliness, contextual clarity, usability, derivation integrity, and rightness or fact completeness. Combining these approaches, DAMA UK (2013) published the six primary quality dimensions:

- Completeness: All required information is available to meet the needs of the users.
- Uniqueness: Information is not duplicated in any records.
- Timeliness: All information is updated and current for the given task.
- Validity: All information follows their pre-defined syntax, including format and type.
- Accuracy: Information correctly reflects its real value.
- Consistency: No discrepancies exist when comparing multiple sets of information.

Therefore, this study adopts the DAMA's six core quality dimensions to analyse the preferred quality characteristics of handover information.

Inevitably, the pursuit of information quality has extended to augment the diverse and specialised handover information needed for the long-sophisticated phase of the building. The case study by Cavka *et al*. (2015) examined the accuracy, reusability, and accessibility of handover information. Thabet and Lucas (2017) highlighted the need to validate the completeness and correctness of handover information to confirm confidence in its quality. Similarly, Becerik-Gerber *et al.* (2012) and Bayar *et al.* (2016) stressed accuracy and accessibility. Provided that the design quality can influence the quality of handover information, Zadeh *et al.* (2017) evaluated the design quality in terms of completeness, accuracy, consistency, compliance, and understandability. These studies offer a broad spectrum of quality requirements but lack alignment with the ISO 8000 series framework for evaluating data quality. As such, additional research is necessary to identify the appropriate quality preferences that effectively cater to the multifaceted activities involved in building management.

This literature review of this study discusses three main topics: (1) commercial building management in the built environment, (2) handover information and its requirements, and (3) the relevant information quality framework. The reviews uncovered several gaps in knowledge. Firstly, there is a lack of clarity on the specific information needed for legal compliances and internal policies in commercial building operations. Secondly, diverse definitions of handover information requirements exist, requiring consolidated interpretations from standard guidelines to clarify their usage and scope. Thirdly, studies have yet to identify specific handover information quality requirements to support the post-construction phase. Consequently, further research is imperative to deepen the comprehension of handover information usage and its quality attributes. This study aims to investigate the intended use of different classifications of handover information and their practical application. The subsequent section will discuss the exploration of the use and quality requirements of handover information.

3. Methodology

This study adopted an exploratory approach to investigate handover information's use and quality dimensions in commercial building management. A rich and real-world context was essential, requiring input from participants regularly using this information in their daily work. Participants from nine organisations managing commercial buildings were selected. It is

191 important to note that the scope of this study is limited to the handover information utilisation in
192 commercial buildings and did not include residential buildings, infrastructure, healthcare, or
193 industrial properties.

194 *3.1. Sampling and recruitment*

195 The researcher utilised purposive sampling to recruit participants from nine organisations
196 that shared similar asset management settings in the US, UK, Northern Ireland, Germany, and
197 Ireland, all managing commercial buildings. This strategic selection aimed to accurately
198 represent the population to gain insightful information from participants' lived experiences,
199 focusing on those with 5 to 23 years of professional experience. Despite initial declines,
200 additional participants fitting the criteria were recruited using the snowball sampling technique
201 (Saunders *et al.*, 2019). These participants, currently managing construction projects, provided
202 valuable insights into the quality of handover information delivered from contractors. Table 1
203 summarises the participants and their areas of expertise.

204

205 **Table 1. List of Participants.**

206

207 *3.2. Data collection*

208 This study selected semi-structured interviews over surveys to collect relevant data.
209 Interviews were deemed appropriate for this study because lengthy, semi-structured interviews
210 provide first-hand experience from participants in organic ways. Semi-structured interviews
211 effectively uncover professional insights and tacit knowledge on the topic under investigation.
212 These interviews allowed participants to express their perspectives. Interviewing continued until
213 saturation was reached, a point where no new information emerged from the participants (Fusch
214 and Ness, 2015).

215 Interview questions were pre-defined into four categories to facilitate specific data
216 extraction: (1) characteristics of buildings, (2) handover information processes and sources, (3)
217 desired information quality dimensions, and (4) handover information management using asset
218 information management tools. Participants described the current handover information usage,
219 highlighting the challenges and limitations of timely access to the correct information. They
220 shared their preferred information quality dimensions for the essential information, drawing from
221 their experiences. Participants had the discretion to abstain from answering sensitive questions.

The average length of the interview process was approximately 60 minutes. Each interview was recorded and transcribed with the permission of the participants.

3.3. Data analysis

This study analysed interview data using qualitative thematic analysis steps outlined by Gioia *et al*. (2013). The initial step involved capturing participants' quotes and phrases describing their experience of using different classifications of handover information for the selected asset management process within the boundaries of each participant's job responsibilities. Block diagrams were created to acquaint the existing asset management processes. Concurrently, first-order descriptive codes were developed from each interview transcript. By performing the data reduction process, these first-order categories were further clustered into broader discussion topics to improve understanding of the use of building handover information (Gioia *et al*., 2013; Easterby-Smith *et al.*, 2021). Before performing a complete analysis, codes were adjusted to maintain data objectively, enhancing the reliability and validity of the final (Weber, 1990).

During the interviews, participants detailed their desired quality attributes of handover information, with a notable emphasis on 'Accuracy'. Only a few participants articulated the ranking of the quality dimensions. To ensure unified results, the terminology of information quality dimensions was aligned: 'Correctness' or 'Correct information' was considered 'Accuracy'. Similarly, 'Up-to-date' information was deemed for 'Timeliness'. Finally, 'Usability' and 'Availability' were judged as 'Completeness', following the definition defined by the DAMA. The data, encompassing varied quality attributes, was organised in a spreadsheet, following the six primary quality dimensions established by DAMA (UK DAMA, 2013). Additionally, radar charts were used to highlight outliers and commonalities in the reported quality attributes, displaying the average frequency reported of each dimension. Chosen for their ability to succinctly exhibit relationships and patterns among multiple variables, making it an effective visual presentation, though they are illustrative and lack statistical significance (Henry, 1995; Saary, 2008).

Adopting a systematic thematic process facilitated the identification and comparison of emergent themes from each participant's narrative and descriptive interview data, leading to meaningful insights. This study explored raw data from asset management professionals to

provide explanatory information that could increase understanding of the use of handover information in commercial building management.

4. Findings

This section presents the identified use of building handover information with the quality preferences. The findings were derived from qualitative thematic analysis of interviews, supported by anonymous quotes from participants identified, such as ID 1 and ID 2, to preserve confidentiality. The research indicates that handover information is used to comply with the organisation's internal compliance requirements and legal obligations, in addition to ongoing asset valuation, capital investment, and decision support for recurring operating expenditures. Table 2 presents a summary of the use of handover information derived from interview findings. These results have been aligned with the discussion topic for an in-depth analysis, offering insights into the application of handover information in commercial building management, as illustrated in Figure 1.

Table 2. Use of Handover Information for Commercial Building Operations.

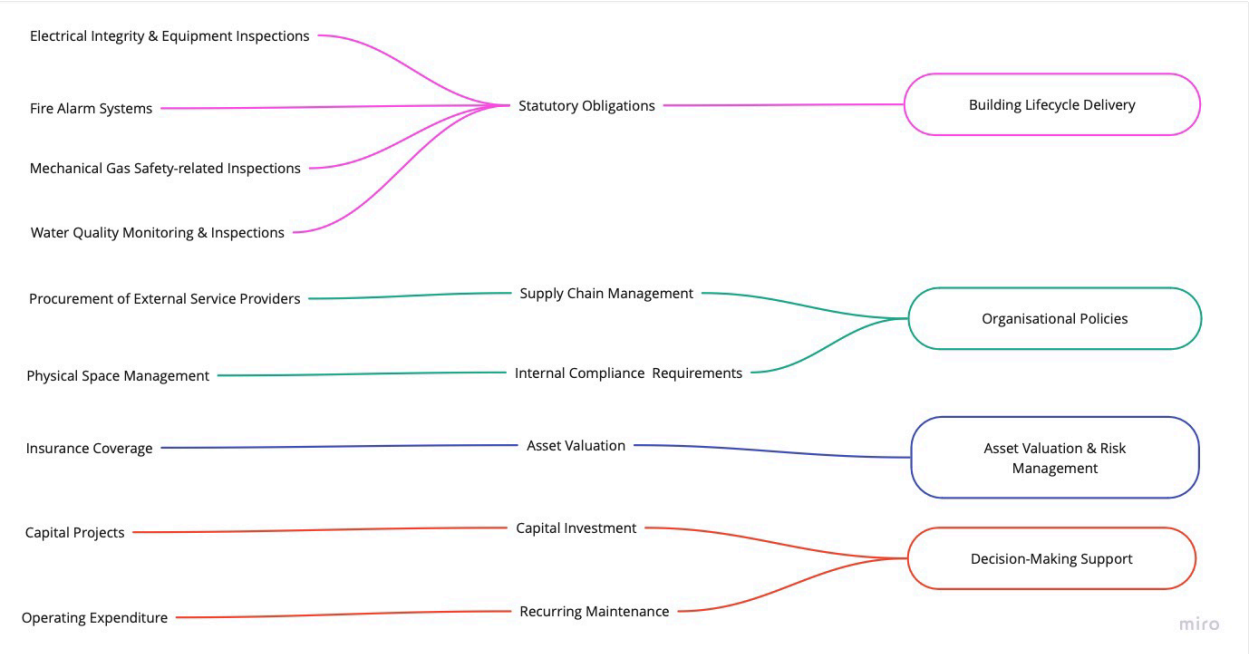

Figure 1. Mapping of the Interview Results to Discussion Topics.

Source: Authors' own creation/work.

4.1. Asset lifecycle delivery

Asset lifecycle delivery involves a series of activities aimed at managing the entire lifecycle of a building. The Institute of Asset Management (IAM) emphasises the significance of meeting compliance-related obligations as part of the lifecycle delivery process, as operating a building is subject to various statutory compliance requirements (The Institute of Asset Management, 2015). Participants reported that handover information is primarily used to comply with statutory-related inspections, such as fire alarm systems and electrical wiring inspections.

Participants emphasised the repeated use of as-built drawings and product information for the inspections of fire alarm systems. According to ID 65, having quality handover information is crucial for managing all fire, life, and safety systems because it ensures statutory compliance around all life and safety-related systems and ties in diversity. Supporting this view, ID 14 added that *'fire alarm systems have been progressive and advanced, employing electronic devices and components through sophisticated relays to provide a comprehensive coverage'.* Accordingly, accurate handover information on the ancillary systems, such as lifts, is also necessary to conduct *'comprehensive testing to ensure the safety of the building users in case of fire…fire [systems] and lifts are tied together. So, it is legally obligated to inspect each lift from the integrated system approach using a complete set of appropriate handover information'* (ID15).

Subsequently, managers of electrical systems asserted the importance of accurately updated as-built drawings and equipment information for various mandated inspections (e.g., ID 27-30, 43, 44, 50, 52, 59, 61-64 & 94). ID 29 argued that *'electrical drawings reflecting the precise locations of electrical gears and connecting wiring are required because equipment such as MCC (Motor Control Centre) and UPS (Uninterruptible Power Supplies) can be installed throughout the building or outside of the building.'* The detailed electrical site plans showing precise locations of assorted electrical equipment, such as transformers, are indispensable for managing a *'high voltage power network'*. Such power-supplying equipment carrying high current demands stringent safety procedures before inspections. Accurately updating these plans, especially after corrections and remedial work, is vital for ensuring safety in subsequent inspections and future work (e.g., IDs 24, 27-30, 61, 62 & 64).

Similarly, as-built drawings and detailed product data are prerequisites for compliance when operating a wide range of gas-fired equipment, such as boilers and water heaters. *'A set of mechanical as-built drawings and product information are necessary to perform a yearly, bi-annually, and full inspection of safety devices on the equipment'* (ID 31). Moreover, considering the importance of inspecting the right equipment, the inspector regularly cross-references *'the equipment plate information, including the make, model, and serial number, with the designated equipment schedule and the associated mechanical drawings'* (ID 31).

Likewise, the participants consistently use a collection of plumbing plans and reliable architectural floor plans for regular water quality testing and routine flush-out as required by local safety regulations (IDs 40 & 42). The plumbing site and floor plans are typically used to locate the building's main inlet and outlet for mandated Legionella testing. Those who manage multiple buildings at remote sites use plumbing as-built drawings to pinpoint the sample collection points for Legionella testing and establish the inspection plans for various buildings. The architectural and plumbing floor plans are also commonly used to identify the locations of plumbing fixtures for routine flushing. Therefore, ID 42 reiterated the significance of accurately updated as-built plumbing drawings to regulate water quality-related issues.

4.2. Organisational requirements

Handover information is used to procure external contractors to perform ongoing compulsory inspections. ID 35, for example, explains that *'a set of as-built drawings and product information is necessary for solicitation purposes together with the narrative scope of work in order to obtain right pricing'.* ID 14 noted that accurate handover information is needed to understand '*your system's maintenance and testing requirements'*. Further, ID 29 argues that reliable electrical as-built drawings and trustworthy product information are required for the contractors, ensuring the 'safety' of the workers when performing high-risk equipment integrity inspections. For these reasons, the information quality dimensions of 'Accuracy' and 'Completeness' were highlighted in addition to updating the relevant drawings and product information.

For internal compliance obligations, the building handover information is used for managing the physical space. ID 1, for instance, relies on the building site plan, floor plans, and room schedules to allocate, monitor, and audit space usage. Annual visual inspections validate space assignments against floor plans, employee data or finance records of designated

departments. While 3-dimensional models are often lauded, , 2-dimensional drawings adequately provide easy visualisations of the pertinent tasks. IDs 2, 6 and 9 focus on 'maximising existing space usage under the guidelines of their organisations' internal compliance requirements due to escalating capital investment costs. A comprehensive, accurate collection of spatial information is preferred for effective management, exemplified by ID 9's practice of cross-referencing space assignments with employee records to enhance the accuracy of the spatial information.

4.3. Asset valuation for risk management

Ongoing asset valuation involves assessing the building value based on different cost elements, such as depreciation, operational, and replacement costs, because the value of a building deteriorates over time (The Institute of Asset Management, 2015). The interviews, however, uncovered that the primary purpose of asset valuation is to determine adequate insurance coverage. Although there is no statutory obligation to purchase property insurance policies, ID 11 noted, *'Organizations are generally risk-averse and want to transfer all risk to an insurance policy and pay a premium. We don't, in general, assume any risks ourselves; therefore, we have almost twenty different insurance policies to cover all types of risks.* Consequently, participants reported obtaining insurance-related documents from handover information. In some cases, insurance-required documents are included in the handover information requirements (ID 3, 4, 13, 23, 35, 40, 61 & 62).

Professional quantity surveyors regularly use handover information to assess a building's declared value, which is crucial in determining insurance coverage. This is essential as some policies penalise for determining inadequate insurance premiums. IDs 1-3, 6 and 7 indicate that buildings and occupant details are also used for renewing liability insurance policies every two years. Buildings with various functions often need multiple policies, prompting insurance companies to conduct annual surveys. ID 12 noted, *'it does not demand a set of handover information at the time of policy purchase, but it is recommended to have accurately updated information available in the event of a claim in order to recover replacement costs'.*

4.4. Decision-making support for capital investment and operating expenditure

For effective asset management, asset owners rely on various sources of information to achieve the expected performance of assets. Asset owners make informed decisions on capital investment and operating expenditure plans to attain this goal. In this context, handover

information provides essential information about the assets at different levels, supporting effective decision-making. Although the decision-making process only partially depends on the handover information, the interviews suggest that handover information can answer many questions about existing systems and equipment within the building.

Participants indicated that handover information assists in making decisions related to capital investment plans and operating expenditures to optimise asset lifespan in a commercial building. IDs 74 and 76 elucidated the use of as-built drawings, technical specifications and operation and maintenance manuals in capital project planning. They noted that *'the handover information can answer many questions about the existing equipment when developing a scope of work'*. The same participants also commented, *'construction documents and as-built drawings, including engineering and operation and maintenance manuals of equipment, are critical to making appropriate decisions for the assets, such as the modernisation, upgrade, and replacement of existing systems'*. Several participants (e.g., IDs 7–13, 16, 33-40, 45-51, & 59-63) concurred with this view. Furthermore, ID 65 and ID 71 shared experiences leveraging handover information to detail technical specifications for the HVAC replacement project.

Transitioning from capital investment planning, the use of handover information is extended to estimate operating expenses from an asset management perspective. Operating expenses are typically estimated using various information, such as work order history and total maintenance expenses. Participants (e.g., IDs 6,16, 23–30, 33, 36, 38, 40, 43, 52- 55, & 59-60) specifically recognise the role of handover information in calculating these expenses in multiple contexts. IDs 4 and 16 highlighted its role in forecasting operating outlays, particularly for the buildings in overseas locations, where different operating strategies necessitate reliance on handover information for budget establishment. Additionally, ID 75 employs as-built drawings to perform a financial pro forma for new spaces or buildings, augmenting annual financial projects for future operational requirements. Furthermore, IDs 66 and 79 use specific architectural drawings such as floor plans, building elevations and site plans to estimate for janitorial services, waste management, window cleaning and landscaping.

4.5. Preferred quality requirements for handover information

Figure 2 presents radar charts depicting the participants' quality preferences of handover information that lead to desired outcomes. The charts indicate a preference for complete and accurately updated handover information for effective task execution. 'Accuracy' emerged as a

key quality dimension, with some participants referring to it as 'Correctness' or 'Precision' depending on their area of expertise. For example, those managing physical space prioritised the accuracy of floor configurations over dimensional accuracy (e.g., IDs 1-5, 8 & 9). Accurate equipment details, such as the serial number and models, were vital, especially for ageing equipment, as handover information often contained outdated information. To counter this, some participants maintained duplicate, updated equipment records (e.g., IDs 15, 27, 31, 34, 52, & 61). Building location information was also deemed crucial by most participants, not just for safety but also for general liability insurance coverage. However, IDs 80-94 cautioned that the accuracy of handover information depends on the timing of its entry into asset management systems, as technological solutions cannot verify the information's accuracy.

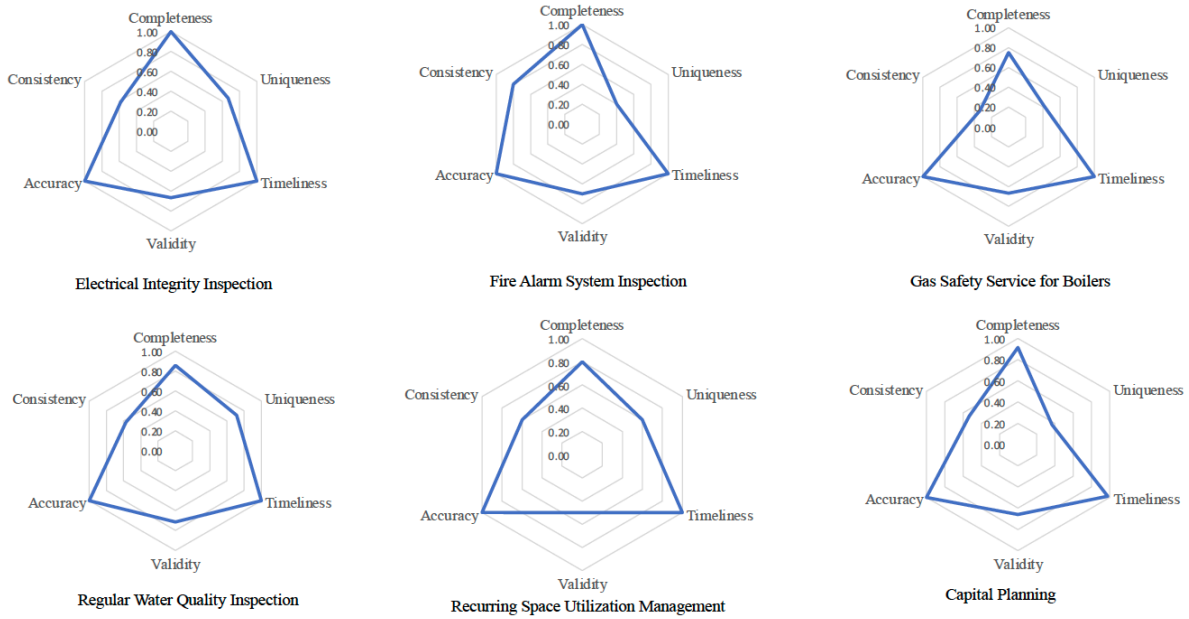

Figure 2. Handover Information Quality Preferences of the Selected Building Operations. Source: Authors' own creation/work.

'Timeliness' emerged as another critical quality attribute, often described as up-to-date, updated, or the most updated information. Some participants used 'Timeliness' and 'Accuracy' interchangeably, emphasising that accurate information requires regular updates (IDs 80, 82, 84, 85, 87-89 & 93). Yet, the challenge of updating handover information for multiple buildings, particularly with minor ongoing projects, was noted (e.g., IDs 6, 7, 18, 19, 27-38, 47, 52, 54, 56, 61 & 62). To combat this, ID 6 noted, *'we've given our cleaning staff tablets so they*

can go around and record stuff that they find around site, take pictures of it, and then stick it back in and we can keep up to date with damage and bits and pieces of the campus'.

Following the emphasis on 'Timeliness' and 'Accuracy', 'Completeness' was also identified as a critical quality dimension, with interpretations varying by expertise. For building appraisals professionals, 'Completeness' entailed all graphical and non-graphical information related to the building. Conversely, it meant for the participants involved in space management was limited to site plans, floor layouts, furniture plans, and room schedules required to perform their tasks effectively. For electrical, mechanical, fire alarm systems and lifts, complete information includes relevant as-built drawings, detailed product information, and operation and maintenance manuals (IDs 18, 20, 27, 30, 31, 33, 35, 36, 43, 44 & 64).

Based on the interviews, 'Accuracy', 'Timeliness', and 'Completeness' were identified as the preferred quality dimensions of as-built drawings, product information, and installation details in the Operation and Maintenance manuals to support effective asset management processes. The quality dimensions of 'Uniqueness' were also merged during the interviews, particularly concerning the addresses of buildings and other asset locations for the safety of workers and occupants.

5. Discussion

The previous section reported evidence-based findings on the application of handover information in the commercial building sector, illuminating the quality preferences derived from participants' experiences. This study emphasises the use of specific handover information, such as drawings and various forms of non-graphical information. Intriguingly, participants had no clear preference for either type in terms of enhancing building operations, presenting a contrasting departure from findings in previous research. This divergence underscores the complexity and varied perspectives in the building operations. Crucially, the efficacy of this information depends on its 'Accuracy', 'Timeliness' and 'Completeness' to achieve the desired outcomes in participants' tasks. The insights drawn from this study point to a more intricate and refined understanding of the significance and utilisation of various reliable handover information forms in the efficient management of commercial buildings.

Interestingly, as-built drawings and product details are among the most frequently used types of handover information. The interviews underscored the importance of accurate and updated as-built drawings, illuminating the need for reliable spatial information in building

446 management. This includes the unique identification of buildings, particularly when managing
447 multiple properties to ensure the safety of employees and occupants. Additionally, as-built
448 drawings are instrumental in optimising space utilisation. Moreover, accurately locating various
449 equipment and non-addressable building support infrastructure is essential for compliance and
450 uninterrupted provision of building services. Unique identification, such as 10-digit codes, is
451 created to eliminate confusion arising from traditionally inherited building names. Further,
452 integrating Geographic Information System (GIS) coordinates enables tracking of outdoor assets,
453 extending even to remote locations (Kurwi *et al.*, 2021).

454 Product details, including manufacturers, models, serial numbers, and technical
455 specifications, are integral to optimising the expected life of assets at various levels (e.g.,
456 equipment and components). These details and as-built drawings are crucial for accurately
457 servicing and inspecting equipment in the correct locations and preparing insurance
458 documentation. Equipment product details are often cross-referenced to ensure accuracy with
459 asset tags and equipment schedules found in as-built drawings and asset registries. Besides, the
460 accurate technical specifications of assets are increasingly important, particularly in managing
461 the replacement of obsolete parts and components to prolong asset lifespan. Inaccuracies in
462 matching this specification can lead to significant system malfunctions, highlighting
463 obsolescence as a critical and growing concern in the building industry.

464 Combining the significance of as-built drawings and product details, this study can guide
465 the future development of BIM incorporating emerging technologies. This integration aims to
466 improve the quality of spatial information and its non-graphical counterparts. Participants have
467 identified that challenges associated with locating outdoor assets have been partly mitigated by
468 employing GIS to pinpoint the locations of buildings and exterior assets. This presents a
469 substantial opportunity to further improve handover information by integrating BIM with
470 cutting-edge technologies, such as the Indoor Positioning System (IPS) and Bluetooth Low-
471 Energy (BLE) beacons. This would precisely determine indoor positions and locations (Li,
472 Cheng and Chen, 2020). In addition, incorporating linked data into BIM could substantially
473 enhance the detail and accuracy of product information related to essential building equipment
474 and components (Farghaly *et al.*, 2019). This holistic approach addresses the needs identified by
475 the building management professionals for efficient operation and maintenance.

476 **6. Conclusions**

The empirical investigation of the use of building handover information and its quality requirements in building management revealed several noteworthy findings. The study underscores the critical role of handover information and its quality requisites for building operations. Inferior quality handover information can compromise occupants' safety and obscure ownership costs. The emphasis is on the need for a clear, reliable 'golden thread' of asset information as mandated by regulations. Additionally, these findings enable asset owners to identify specific handover information requirements in future building projects.

This study offers theoretical and practical contributions. Theoretically, this study validates the proficiency of building management professionals in understanding handover information requirements, challenging the previously held notion of a 'catch-all' approach by building owners. This earlier approach was attributed to an unclear understanding of the intended use of the information. Practically, this study affirms the critical role of handover information in building operations, identifying specific areas where the use of inferior-quality handover information can result in negative outcomes. This dual contribution enhances understanding of the importance and practical implications of handover information in building management.

Although this study has altered our understanding of handover information use, its limitations must be recognised. The insights drawn from specific building sectors may not represent all perspectives in building management. To strengthen the study's generalisability, future research needs to broaden its scope and increase the sample size, incorporating a wider variety of cases and participants. Such expansion would significantly enhance the reliability and relevance. Future research should also focus on defining clear and specific information requirements for BIM-based building management to further refine the understanding and application of handover information.

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