Evaluating Digital Tools for Construction - FM Handover

A Directed Research Project

by
Kalyani Vijaykumar Dehankar
PCM24485

Submitted to the Office of Faculty of Technology, CEPT University
in partial fulfilment of the requirements for the degree of

MASTER OF TECHNOLOGY- CONSTRUCTION ENGINEERING & MANAGEMENT

Guide: Siddharth Panjwani

Co-guide: Dr Amarnath CB

CEPT UNIVERSITY

Faculty of Technology
Kasturbhai Lalbhai Campus, University Road, Navrangpura, Ahmedabad-380 009 India.

Evaluating Digital Tools for Construction - FM Handover

A Directed Research Project

by
Kalyani Vijaykumar Dehankar
PCM24485

Submitted to the Office of Faculty of Technology, CEPT University
in partial fulfilment of the requirements for the degree of

MASTER OF TECHNOLOGY- CONSTRUCTION ENGINEERING & MANAGEMENT

Guide: Siddharth Panjwani

Co-guide: Dr Amarnath CB

Faculty of Technology
Kasturbhai Lalbhai Campus, University Road, Navrangpura,
Ahmedabad-380 009 India.
www.cept.ac.in

ABSTRACT

The transition from construction to Facility Management (FM) represents a critical juncture in the building lifecycle where extensive project intelligence is frequently lost due to fragmented data practices. Despite the proliferation of Building Information Modelling (BIM) and Common Data Environments (CDEs), the AEC industry lacks a coherent, practitioner-facing methodology for aligning digital tools with specific handover activities. This research addresses this structural gap by developing a systematic tool-evaluation framework. The study investigates how data quality, safety, scalability, and productivity impact the efficacy of digital handovers, aiming to move beyond vendor-driven selection toward an evidence-based approach grounded in operational objectives.

A mixed-methods research design was employed, combining a comprehensive review of post-2021 literature, including ISO 19650 and openBIM standards with semi-structured interviews with industry experts across various regions. Findings reveal a significant geographical asymmetry in BIM maturity, where adoption often stalls at the 5D stage in emerging markets while advancing toward 7D integration elsewhere. Furthermore, the study identifies three distinct handover modalities ranging from manual to platform-driven workflows. The results suggest that handover failures stem not from technological immaturity, but from the absence of an operational roadmap that links specific activities, such as testing and commissioning or snagging, to their respective information requirements and tool capabilities.

The primary contribution of this research is the Construction-to-FM Handover Tool Evaluation Framework, a nine-stage hierarchical model that prioritizes activity-based requirements over software features. Unlike existing models that focus on organizational or platform levels, this framework operationalizes evaluation at the task level, ensuring market-fit assessments are rooted in data reality. Theoretically, it extends contemporary BIM-FM integration literature by providing a granular lens for digital tool assessment. Practically, it offers a transparent, scalable decision-support instrument for project teams and owners, ultimately reducing information loss and enhancing the operational readiness of assets from the point of occupancy.

UNDERTAKING

I declare hereby that the work presented in this Directed Research Project document "Evaluating Digital Tools for Construction–FM Handover" by me, Kalyani Vijaykumar Dehankar, PCM24485 submitted towards partial fulfilment of the requirements for the award of the degree M.TECH. IN CONSTRUCTION ENGINEERING AND MANAGEMENT at the Faculty of Technology, CEPT University, Ahmedabad is an authentic record of my own work carried out during the period of Spring 2026, under the supervision of Siddharth Panjwani and Co-guide Dr Amarnath CB. Neither the data, nor any other content of this report have been copied. This work has not been previously submitted to any other institution for the award of any degree/diploma. I understand that my result and grades can be revoked if later it is found to be plagiarised or previous work resubmitted.

Name of student	: Kalyani Vijaykumar Dehankar
Code No.:	: PCM24485
Date	:
Place	: Ahmedabad

Disclaimer

This document describes work undertaken as part of the Master of Technology in Construction Engineering and Management program at the Faculty of Technology, CEPT University. Author is solely responsible for all views and opinions expressed therein, and do not necessarily represent those of the institute.

CERTIFICATE

Title of the DRP : Evaluating Digital Tools for Construction–FM Handover

Name of the Student : Kalyani Vijaykumar Dehankar

Code No. : PCM24485

The above titled study by the student is approved as a creditable work on the subject carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a pre-requisite for the degree of Master of Technology (Construction Engineering & Management) for which it has been submitted.

It is to be understood that by this approval, the undersigned do not endorse or approve the statements made, opinions expressed or conclusion drawn therein but approves the study only for the purpose for which it has been submitted by him/her and satisfies the requirements laid down in the academic programme.

Signature of the Guide : ………………… Signed on 30 April 2026

Signature of the Co-guide : ………………….

ACKNOWLEDGEMENTS

I would like to extend my heartfelt gratitude to all those who have contributed to the successful completion of my Design Research Project (DRP), undertaken as part of the master's program in Construction Engineering and Management at CEPT University, Faculty of Technology.

I am especially grateful to my Guide Siddharth Panjwani and Co-guide Dr Amarnath CB for their exceptional mentorship, constructive critiques, and consistent support. Their academic insight and encouragement were critical to shaping the rigor and relevance of this research. Their dedication to fostering independent thinking and pushing academic boundaries significantly influenced the depth and quality of my work.

I would also like to acknowledge the faculty and staff of CEPT University for cultivating an intellectually stimulating and collaborative environment that enabled the pursuit of research excellence. My sincere appreciation extends to my peers, colleagues, and industry professionals, whose valuable suggestions and perspectives significantly enhanced the quality and applicability of my work.

Finally, I am deeply thankful to my family for their unwavering support, understanding, and belief in my aspirations. Their encouragement was a constant source of motivation throughout this journey.

To all who contributed to this endeavor, thank you for making this research experience truly enriching and impactful.

Kalyani Vijaykumar Dehankar
PCM24485

ABBREVIATIONS

AIM	Asset Information Model
AIR	Asset Information Requirements
BIM	Building Information Modeling
BEP	BIM Execution Plan
BSI	British Standards Institute
CAFM	Computer-Aided Facility Management
COBie	Construction-Operations Building Information Exchange
CDE	Common Data Environment
EIR	Exchange Information Requirements
LOD	Level of Development
IFC	Industry Foundation Classes
ISO	International Organization for Standardization
O&M	Operations and Maintenance
PDF	Portable Document Format

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

CHAPTER-1: INTRODUCTION

The AEC industry is going through a digital transformation acquiring technologies (BIM, CDE and cloud collaboration tools) to alter the way information around building is generated, processed and communicated across various stages of its project life cycle. The AEC industry is moving away from traditional document-based workflows toward integrated digital ecosystems that enable stakeholders to coordinate in real time and make informed decisions through data reliance and transparency. This enables process efficiencies during design and construction and extends into new methods of transfer of information for operation beyond it.

When it comes to the final handover between construction and FM, nothing is more important than data which means that the way in which they give up all asset information at this stage influences the building's long-term performance. It is this data quality, integrity, and completeness that will dictate whether FM personnel can safely operate and maintain that asset without requiring rework or information loss. For data to be delivered timely to FM personnel in a way that allows for potential (re)use, it must exist in structured data formats that allow for effectiveness, searchability and interoperability.

Digital tools, like BIM authoring software, field management applications, and CDEs, help compile, verify, and share project information during handover. They manage many tasks, including commissioning, snagging, and document management. This is possible because they make workflows more efficient, reduce manual effort, and centralize validated, usable asset data. When used properly, these technologies make the handover process more effective and accurate, which then leads to a smoother transition into facilities management.

Even with progress in data standards and digital tech, there's still a gap between the data shared during handover and what the tools using it truly need. These tools depend on complete, well-structured, and linked information. But often, the data they get is incomplete, unstructured, or just poorly organized. This mismatch means even advanced tools don't get used to their full potential; they need manual fixes or just sit idle because they can't handle the data's quality. So, the issue isn't the tools themselves, but how poorly the data quality lines up with what those tools need.

Another major challenge for the industry is the lack of a consistent, systematic way to pick digital tools during handover. Often, teams choose tools based on factors like cost, user experience, or vendor recommendations, instead of carefully looking at project needs, data requirements, and long-term operational goals. Without a clear method to evaluate options, organizations have trouble finding the right fit for their specific needs. This results in inconsistent use of digital tools and limits the benefits they could offer.

Without established processes, many companies just fall back on informal methods for handover and technology selection. Decisions to set up these processes or pick a tool are often reactive, not strategically planned. They often hinge on things like project constraints, stakeholder preferences, or immediate operational needs. This leads to fragmented workflows, inconsistent tool use, and little uniformity across projects. These informal ways cut down on efficiency, scalability, and repeatability, making it harder for an organization to build and keep up strong digital process capabilities throughout its whole portfolio.

1.1 Research Aim

To develop a tool-evaluation framework that helps construction and FM organizations assess digital tools for the handover phase based on handover data quality, safety, scalability, and productivity impact.

1.2 Research Objectives

- **Objective 1:** Understand how handover data quality and structured formats affect the performance and usability of FM digital tools
- **Objective 2:** Investigate how contractors and FM teams currently select digital tools for handover workflows
- **Objective 3:** To establish a set of evaluation criteria that is critical for assessing tool performance during the construction-to-FM transition and to propose a structured, easy-to-use digital tool evaluation framework for practitioners.

1.3 Scope of Work

The scope of the study is strictly limited to FM/construction handover phase of the project lifecycle with a practical use. This study only focuses on the handover aspect of the project lifecycle, while the design and construction phases are left out in detail. Therefore, the perspective of the project owner (or client) will be the primary consideration in the study, and major stress will be laid on the needs of the project owner in view of his use of the asset for the long term. Therefore, the scope of the study is limited to an evaluation of the functional capabilities of the types of digital tools used in the context of the handover phase.

1.4 Timeline and Work Plan

Table 1- 1: DRP Timeline

Phase	Week	Activities
Phase 1 Literature Review	Week 1	Literature review across national and international standards
	Week 2	Study handover practices, digital environment
	Week 3	Define scope of study, select research methodology
	Week 4	Preparation and submission of commencement report
	Week 5	Study existing tool selection literature
Phase 2 Data Collection & Analysis	Week 6	Identify gaps and develop interview guide
	Week 7	Conduct semi structured interviews, document the findings of interviews conducted
	Week 8	Preparation and submission of interim progress report
Phase 3 Framework Development	Week 9	
	Week 10	Analyzing the differences in literature study and interviews
	Week 11	Create conceptual diagrams; draft tool evaluation framework
	Week 12	Refining and compilation of findings into structured report
Phase 4 Reporting	Week 13	Preparation and submission of qualifying report
	Week 14	
	Week 15	Preparation of submission of Research Paper
	Week 16	

CHAPTER-2: LITERATURE REVIEW

2.1 The Construction Project Lifecycle and the Handover Phase

The project lifecycle shows how a building's information changes from the first idea to its long-term use and upkeep. BIM is used to create coordinated 3D models with basic project data starting at the design stage. These models are then gradually filled in with more information by different people, including architects, engineers, and consultants. As the building goes up, the model becomes a more complete repository of information, including installation details, specifications, and commissioning data. During the handover, this information should turn into an as-built model that meets the needs of the assets. This model will be the basis for the Asset Information Model (AIM). During the FM phase, BIM continues to help by giving people access to organized asset data for maintenance, performance monitoring, and making decisions about the lifecycle of the assets.(Mayo, McCuen, and Shelbourn 2023)

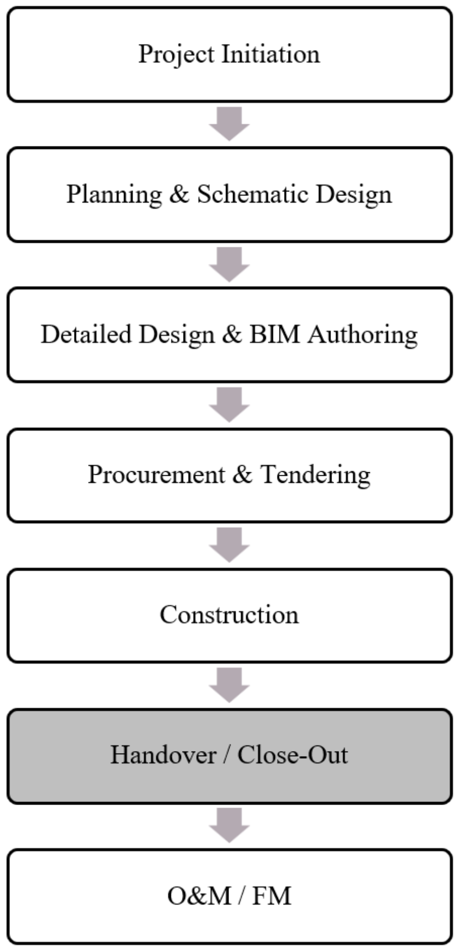

Figure 2-1: Project lifecycle

As the BIM-enabled project goes through its different stages, data is created bit by bit. Different stakeholders add information that is specific to their field, and together this information makes a complete asset data repository. This staged data development makes sure that information goes from ideas to detailed, ready-to-use asset data.

Appendix 1 shows a complete list of all the data, information, and documents that stakeholders create during the BIM lifecycle (Based on: ISO 19650, 2018; Mayo, McCuen & Shelbourn, 2023; Tsay, Staub-French & Poirier, 2022; Otranto et al., 2025; Chatsuwan, Ichinose & Alkhalaf, 2025; Carvalho et al., 2023).

2.1.1 Importance of Handover Phase

Handover is a distinct phase in the construction project cycle that occurs after the building has been completed but before the onset of standard operations. This is often called the project closeout and handover in literature. Literature refers to this stage as project closeout/handover and entails separating a handover point as another construction project life cycle step after building completion and commissioning but before normal operations commence. At this point, the contractor provides the owner with all the information he needs, including as-built drawings, operation and maintenance manuals, warranty information, and system testing reports. They also ensure that the building meets all the contract requirements and legal obligations such as an occupancy certificate. This transition phase is critical as it officially prepares the project for safe, long-term use by the FM team, who will oversee the daily operations and maintenance tasks. (Mayo et al. 2023)

Poor handover leads to incomplete, inconsistent, or unstructured information about the assets and the facility management teams are forced to depend on data reconstruction manually and through redundant verification on the site. This results in operational inefficiencies, high maintenance costs, and lack of optimum building performance over its building lifecycle. Research by Tsay, Staub-French and Poirier (2022) demonstrates that the information relevant to FM must be deliberately planned and assigned to specific stakeholders and validated against formal information requirements established at the beginning of a project.

Detailed table with all critical FM deliverables along with responsible stakeholders is given in Appendix 2.

2.1.2 Activities Involved in Handover Phase

Handover phase encompasses a series of coordinated technical, administrative, and documentation-related activities that ensure the building is complete, compliant, and ready for operation. Studies highlight that the handover phase encompasses testing & commissioning, snagging, documentation handover, closure & formal handover, which are critical for ensuring building performance and smooth transition to facility management. (Asare et al., 2023).

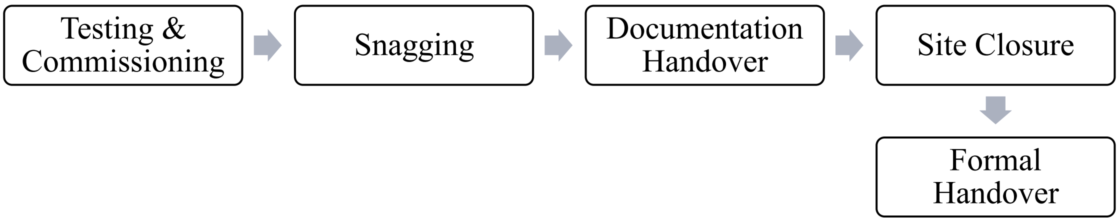

Figure 2-2: Activities involved in handover phase

The table below indicates the works included in specific handover activity. It gives clear understanding of what type of work needs to be done e.g. on-site checking, compilation of information or issue tracking and so on.

Table 2- 1: Activities and works involved in Handover Phase

Sr.no.	Activities involved	Works included
1	Testing & Commissioning	• On site testing and verification of performance of building systems against design intent • Commissioning of building systems
2	Snagging	• Checking for defects/incomplete work • Rectification of defects/incomplete work • Final verification and closure of defects/incomplete items
3	Documentation Handover	• Compilation of as-built drawings and models, Validated COBie sheet, Full O&M Manuals, T&C records and reports, Warranty & Guarantee Certificates, Spare Parts Lists, Preventive Maintenance Schedules, all OC & NOCs, AIM, Financial account records • Submission of compilation of handover documentation package
4	Site Closure	• Site cleaning and removal of temporary works, demobilization of resources and equipment
5	Formal Handover	• Client approval and acceptance • Transfer of ownership and occupancy • Project completion certification

2.2 Evolution of Handover Practice: From Paper-Based Documentation to Digital Environments

The transition from traditional to digital handover represents a fundamental shift in how building information is captured, stored, and utilized. This evolution moves away from static, fragmented documentation toward dynamic, integrated data environments.

2.2.1 Traditional Handover: Limitations and Information Loss

Traditionally, the handover process has been a document-centered one, involving, for instance, handing over huge volumes of folders by the contractors to the owners of the project containing documents such as as-builts, warranties, and maintenance guides. This traditional technique, which mostly involves physical documentation using scanned copies of documents in the form of PDFs, results in information that is difficult to access and easily lost. One weakness associated with this technique is that it often entails the loss of vital information during the transition period between the construction phase and the operation phase. In most cases, facility managers end up conducting site surveys to collect information that should have been conveyed before. (Pishdad-Bozorgi et al., 2022; Sarkar & Majumder, 2023; Zanni et al., 2022).

2.2.2 Digital Handover: BIM, CDE, and Structured Data Standards

The modern methods of handover rely on BIM and CDE, making sure that all the information on the building can be accessed through them by the facility management team. Unlike traditional methods of handing over, the modern methods of handing over are based on the implementation of structured data formats, such as COBie, which allows one to avoid the need to manually enter information into CMMS. By implementing modern methods of handover, one can ensure that there will be no risk of losing essential information about warranty terms, maintenance needs, and so on, getting the so-called "digital twin" of the real asset. Facility managers can conduct search queries via keywords and obtain good quality information regarding warranties, maintenance needs, and other characteristics of the asset.(Chatsuwan, Moriwaki, et al. 2025; Eastman et al. 2018; Tsay et al. 2023)

In recent work, openBIM methods are increasingly addressed where information is built into models and checked by pre-defined exchange formats that enhance coordination, visualization, and data retention throughout the lifecycle. CDE platforms, in parallel with digital integration methods such as BIM-FM, facilitate current data usage, commissioning validation, and handover into CAFM/CMMS. Emerging areas such as the use of the semantic web for information handover is still at the research level, and is expected to offer an improved lifetime data usability.(Chatsuwan, Moriwaki, et al. 2025; Dulguun 2023)

2.2.3 The openBIM Ecosystem: IFC, COBie, IDS, and BCF

With these advancements of openBIM standards made by buildingSMART International, Facility Management receives an innovative technology that opens doors to a more efficient process. It removes barriers and breaks restrictive proprietary siloes that hinder facility management from using the collaborative, vendor-neutral approach. As a result, with the integration of standards of data (such as IF and COBie) facility management obtains high-quality, easily manageable asset data that will seamlessly flow from the construction stage into operations with no need to transfer data manually. Data exchange capabilities will be strengthened by workflow and communication standards. For instance, with the use of MVDs and IDS, only the relevant machine-readable asset data is transferred, and at the same time, bSDD serves to standardize technical definitions and prevent misunderstandings from software to software. Overall, through openCDE APIs and BCF it is possible to have well-synchronized records of an asset that can be stored in numerous digital devices, therefore providing up-to-date asset data at any given point in time in regard to equipment, warranties and its position in the space. (Otranto et al., 2025; Chatsuwan, Ichinose, and Alkhalaf 2025)
openBIM Ecosystem is divided into categories of Data Standards, Workflow Standards, and Communication Standards.

1. Data Standards (File Formats)

These are fundamental file formats which allow transferring actual model information and handover data.

i. IFC (Industry Foundation Classes): The 'PDF of BIM.' It is the key openBIM file format (ISO 16739). This file format allows exchanging geometrical, spatial, and rich information between software applications, e.g., from Revit to Archicad. Common file extensions: .ifc, .ifczip, .ifcxml.

ii. COBie (Construction Operations Building Information Exchange): An open data format aimed at collecting information about assets (equipment list, warranty information, replacement parts). The format is generally delivered in Excel (.xlsx) or CSV format. COBie plays a significant role during the handover phase to Facility Management.

2. Communication & Workflow Standards

These standards cover communication and filtration of data for a particular purpose.

i. BCF (BIM Collaboration Format): An open file format that is used for issue tracking. As opposed to transferring a huge file with a size of 500MB to show 'clash,' a BCF file format is being transferred. BCF is basically a small package containing a snapshot, viewpoint (camera location), and comment attached to that snapshot.

Common file extensions: .bcf, .bcfzip.

ii. IDS (Information Delivery Specification): This is a relatively new standard which describes in detail what information should be present in the model in a machine-readable format. IDS allows automatic validation of IFC files according to the project specifications.

iii. MVD (Model View Definition): Subset of the IFC Schema. Given that an IFC file contains all types of data possible, MVD is used to extract data relevant to its particular application such as "Coordination View" or "Structural Analysis View".

iv. IDM (Information Delivery Manual): Mentioned in the context of ISO 19650 standards, IDM refers to a technique for specifying information requirements and exchange procedures. It is specifically referred to in ISO 19650-1:2018 (5.4.3) in the context of project information requirements and in ISO 19650-2:2018 (5.6.3) as a technique for validating information quality.

3. Services and Dictionary Standards

i. bSDD (Building SMART Data Dictionary): A cloud-based service that correlates technical terminologies and classifications with standardized meanings. This guarantees that when someone says “Window,” there is an exact meaning known by the software, regardless of the language or software being used.

ii. openCDE APIs: A collection of APIs developed to facilitate seamless communication between various Common Data Environments (CDEs). (Chatsuwan, Moriwaki, et al. 2025; Matarneh et al. 2022; Otranto, Junior, and Pellanda 2025)

2.3 Information Management Frameworks

2.3.1 ISO 19650 (OIR, AIR, EIR, AIM)

ISO 19650 series set out an international standard of how to manage information using BIM for all stages of the built asset lifecycle - planning, design, delivery, and into operation/facility management. It includes both principles, roles and processes, and the information requirements to enable standardized, consistent and high-quality exchange of information between parties, avoiding ambiguity and data loss.

ISO 19650 series set clear definition of Organizational, Asset, Project, and Exchange Information Requirements (OIR, AIR, PIR, EIR), which specify what information is needed, why, by whom, and when across project phases.

Table 2- 2: ISO 19650 Information requirements

	OIR	AIR	PIR	EIR
Full Name	Organisational Information Requirements	Asset Information Requirements	Project Information Requirements	Exchange Information Requirements
Who defines it	Owner / Organisation	FM team / Asset Manager	Client / PM	Client / BIM Manager
Scope	Whole organisation & portfolio	Individual assets	Single project, per stage	Single project, per deliverable
Question it answers	What does our organisation need to know?	What data does each asset need to be operated?	What do we need to know to make project decisions?	What must the supply chain deliver, when and how?
Feeds into	AIR + PIR	AIM / COBie / CMMS	Data Drops	BEP / Data Drops
Level of specificity	Broadest	Asset-specific	Stage-specific	Most specific & contractual
ISO 19650 Clause	Clause 5.1	Clause 5.1	Clause 5.1	Clause 5.2

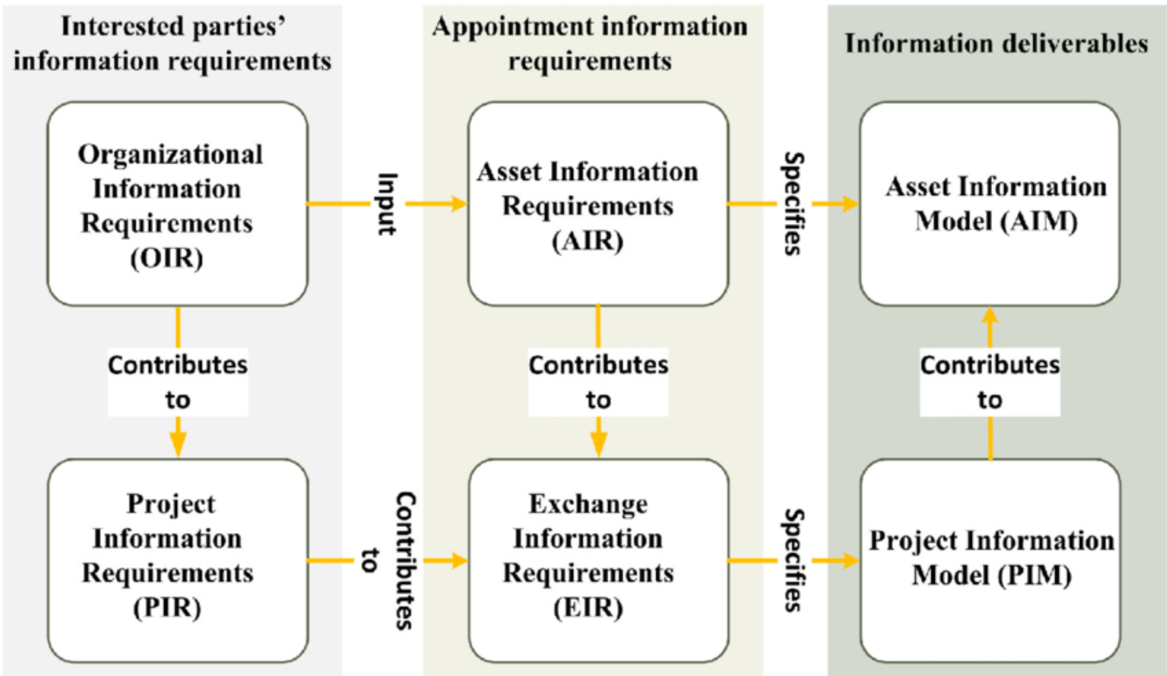

Figure 2-3: Flow of Information Requirement

Source: Su et al., 2021

Together these four sit inside the overall umbrella term: "Information Requirements" (ISO 19650-1, Clause 5.1) - with OIR at the top driving everything below it, and EIR at the bottom being the only one that flows outward to the supply chain as a contractual instruction.

2.3.2 LOD Framework

The Level of Development (LOD) concept put forward by the American Institute of Architects (AIA) is a known way of expressing the extent to which an element in a BIM model should be considered fully developed at different project stages. Originally introduced by AIA through digital practice documents such as AIA G202 and E202 in order to help project teams communicate about the extent of model element development at each project milestone in terms of contractual expectation and good communication among stakeholders. LOD is a scale of model element development in numerical values (ranging from LOD 100 up to LOD 500) where a higher LOD value indicates more information in the model element. The LOD value progression is from abstract to fully detailed (from LOD 100 to LOD 500), where LOD refers to the amount of information that can be derived from the geometric and non-geometric information. LOD Specification is now handled by the BIMForum – an organization based on the initial LOD definitions of AIA. LOD Specification details the requirements for LOD for all kinds of building elements and ensures that there is proper understanding of this data contractually.

Table 2- 3: BIM Level of development

LOD level	Model Development level
LOD 100	Pre - design
LOD 200	Schematic design
LOD 300	Design development
LOD 350	Construction and documentation
LOD 400	Construction stage
LOD 500	As built

"LOD" of BIM is definitely the most talked about and overused acronym in the business. As different LOD requirements exist in different models, as well as different LOD level descriptions, every single professional will possess their own version of interpretation for a given LOD level description and thus the detail to be included in a given model, and as such the inconsistency in such descriptions may lead to great misunderstandings and increased risks associated with a project. In order to clear any kind of ambiguity regarding such statements, levels have been classified according to subscripts like LODi, which stands for Level of Detail

- Information, or LODt (stands for Level of Development, introduced for terminological clarity). These are non-ISO definitions and should be taken into consideration according to certain contextual framework.

Table 2- 4: Details of Multiple LOD Sub-terms

Notation	Full Term	Origin	What It Measures
LODg	Level of Graphical Detail	Academic	Geometric fidelity, shape, dimensions, visual resolution
LODi	Level of Information Detail	Academic / PAS 1192-derived	Non-graphical data: attributes, specifications, FM properties
LODt	Level of Development (term)	Academic	Overall development maturity geometry *and* information combined; used to avoid ambiguity with LOD as "Level of Detail"
LODti	Temporal Level of Detail	Academic	Time granularity in 4D simulation contexts
LOIN	Level of Information Need	ISO 19650-1	current international standard replacing LOD/LOI, specifying information requirements by purpose

2.3.3 Data drops and structured delivery

The data drop refers to the formal passing of project-related information from the supply chain (design team, contractor, BIM manager) to the client on a particular stage of the project. A data drop is not about transferring the data via any means such as attaching the file in an email but about controlled information sharing that is agreed upon between parties. The specific type of data (modeling, information, drawings, and others) that is required by the client at a certain stage of the project to make an important decision, get their approvals or receive the building. It acts as a check point in the project as one cannot proceed to the next level of the project until the necessary information has been exchanged successfully. Developed as part of the United Kingdom government's BIM level 2 program,
PAS 1192-2:2013 *Specification for information management for the capital/delivery phase of construction projects using building information modelling*, published by the **British Standards Institution (BSI).** This is the document that first formally defined Data Drops as structured, milestone-linked information exchanges within a BIM-enabled project workflow.

Table 2- 5: Phases of Data Drop

Source: BSI

	Drop 1	Drop 2	Drop 3	Drop 4
RIBA Stage	Stage 2	Stage 4	Stage 6	Stage 7
Milestone	End of Concept / Schematic Design stage	End of Technical Design / Pre-tender	Practical Completion	During Operations & Maintenance
Decision gate	Proceed with design	Proceed with construction	Hand over building	Proceed with alterations
LOD level	100–200	300–350	500 (as-built)	Updated as required
Model type	PIM (concept)	PIM (construction)	AIM (operational)	AIM (updated)
Key deliverable	Concept models + cost plan	Federated model + full spec	COBie + O&M + AIM	Updated AIM + POE data
Primary recipient	Client / PM	Client / Contractor	FM team / Asset owner	FM team / Asset owner
If missed or incomplete	Design proceeds on wrong assumptions	Construction awarded without full information	FM team cannot operate the building	Asset managed on outdated data

2.4 Challenges in Handover Phase

Recent research consistently identifies several challenges in digital handover processes faced by FM teams across three dimensions; process, technology and human/organization challenges.

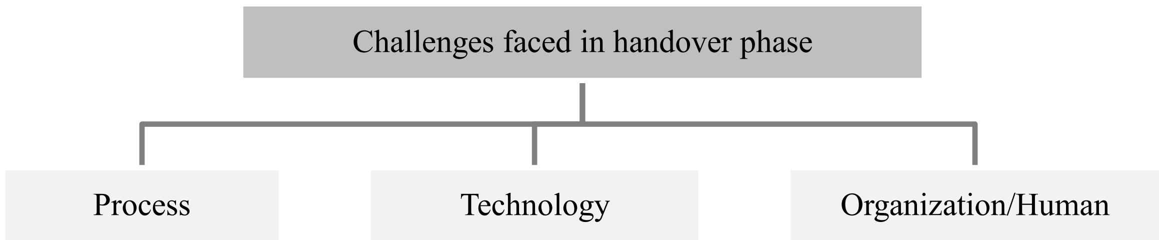

Figure 2-4: Challenges in Handover Phase

1) Process Challenges

The handover stage in a project is strongly impacted by process related inefficiencies, specifically the late arrival of information and absence of a structured way of working. Investigations reveal that handover information is often generated and handed over only at the end of a project, leaving no time to validate, correct or align it to FM requirements. This leads to incomplete, unaligned information being handed over to FM teams who then spend considerable time manually reworking the delivered information, or whose work is compromised due to insufficient and inconsistent data. Furthermore, the absence of precise requirements regarding what information to provide, in what format and at which point can result in unclear and inconsistent information delivery, and undermine the purpose of digital handover. Another problem with processes is the very low involvement of FM stakeholders in the early stages of a project, leading to information being delivered that is not fit for operational purposes. As studies demonstrate that misalignment of OIR, AIR and EIR results in information unfit for FM use, a clear definition of these requirements would be beneficial. However, the problem is further amplified by poor workflow, and no clear definition for acceptance criteria, resulting in inefficient validation.(Ichendu and Irimiagha 2024)

2) Technology Challenges

The "technological problem" still one of the greatest difficulties for achieving digital handover effectively. Interoperability problem and the scattered information make the problem more difficult. Although there are open standards such as IFC, COBie used, research shows that implementation of schemata remains inconsistencies, semantically differences and lacks of simultaneous bi-direction information exchanging between tools. It ends with data loss, redundancy and inefficiency on the delivery of data from BIM to FM tools. In addition to that, due to the existence of various kinds of isolated tools, the "fragmented digital environment" can't help to create an effective and credible data ecosystem.

Poor data quality, insufficient data information and structure of data also weaken the usability of the deliverable from digital handover. For example, delivery information in a non-machine-readable format, or lacks the detailed information needed for FM operation led to the underutilization of BIM data after the projects finished. Meanwhile, the complexities of tools and variability in functionality cause the technology problem. Due to the support of the standard and data extraction ability differ, it results in that various tools make different problems.(Izbash and Babayev 2024; Ichendu and Irimiagha 2024)

3) Human/Organization Challenges

Some key human and organizational challenges include factors preventing the effective implementation and use of digital tools during the handover process. Skill and competency of stakeholders, especially FM team members, are the primary reasons why BIM and other digital tools fail to get implemented. In line with various studies, high degree of technological complexities and steep learning curves result in poor stakeholder involvement and engagement in digital-based practices. Poor skills of stakeholder thus result in wastage of investments made in digital technologies and continuous reliance on traditional means of doing things.In addition, resistance to implementing digital systems and data validation concerns further become hindrances for successful implementation. Organizational resistance to change and mistrust in digitalized data result in low levels of adoption of digital technology for managing handovers. The findings show that incentive misalignment among stakeholders further reduces motivation to develop useful data for FM, which only gets developed during later project phases.(Khan et al. 2024)

According to my findings, digital tools are data-dependent systems whose performance is determined only by the level of quality and completeness of data provided. Process-related issues such as late data delivery and insufficient involvement of FM at an early-stage lead to inconsistency within the created datasets, which in turn affects negatively the performance of digital tools, preventing them from becoming a "single source of truth" for a project owner. In addition, there are technical problems associated with standardization that also affect the performance of digital solutions. Besides, issues related to human factors such as resistance to using digital tools and skills gaps lead to low utilization, not due to any flaw in the digital tools themselves but rather because of low-quality data preparation. In conclusion, this research validates the notion of research objective 1 that high-quality data and organized data serve as multipliers for digital tools, improving their efficiency. On the contrary, low-quality data serves as a hard cap on digital tool efficiency.

2.5 Existing Tool Evaluation Frameworks: A Critical Appraisal

In recent years, evaluation frameworks utilized when assessing handover tools during the transition period from construction phase to facility management have moved from general evaluations based on Information Technology to frameworks which focus on the flow of data and on interoperability and client requirements. According to the authors of these studies, it is advisable to conduct an evaluation which will assess the capability of the tool in meeting the data standard criteria, including COBie and IFC, while addressing the problem of "Information Loss." Further, assessment criteria for digital tools for FM have shifted from mere financial assessments to multicriteria decisions with regard to data interoperability and maturity of the organization.

Table 2- 6: Summary Table of Post 2021 Tool Evaluation Frameworks

Author(s) & Year	**Framework Name / Focus**	**Core Evaluation Criteria**	**Key Contribution to Handover**
Zanni et al. (2022)	BIM Handover Solutions Framework	Process integration, data interoperability, and stakeholder collaboration.	Identifies "bottlenecks" in digital tools that prevent seamless construction-to-operations flow.
Pishdad-Bozorgi et al. (2022)	BIM-FM Integration Maturity Model	Data richness, system connectivity, and organizational digital readiness.	Evaluates tools based on their ability to create an "Integrated Workplace Management System" (IWMS).
Sarkar & Majumder (2023)	Handover Challenge-Capability Matrix	Data safety, technical usability, and information completeness.	Maps specific digital tool capabilities against common handover inefficiencies (e.g., fragmented workflows).
Kopsida & Brilakis (2024)	Digital Twin Readiness Assessment	Real-time data synchronization, geometric accuracy, and asset connectivity.	Evaluates if a tool can maintain a "Live" Asset Information Model (AIM) post-handover.

There are already quite a few pieces of research work done in the realm of digital handover. They have provided substantial insights into where things go wrong and why they do so. There have been mappings done on BIM-to-FM handover failures related to data interoperability; human and organizational resistances for digital implementation have been documented; and there have even been frameworks offered, which include tool choice within the scope of overall organizational digital readiness. The only thing that the current literature is unable to offer and which all industry professionals need is a step-by-step roadmap of actions**.**

This discrepancy is much more than theoretical. It arises whenever a commissioning engineer cannot complete a test record electronically for the asset because the asset ID is missing from the CDE. It occurs every time a snagging application takes a photo of a defect that is unable to be linked to an element in the BIM model because the BIM model has not been configured for handover. It arises when a documentation controller completes a COBie spreadsheet, which subsequently fails automated testing because no-one at any point in the lifecycle defined what constituted a successful completion. In all cases, the issue is not about the absence of tools or knowledge of the standards but rather the fact that the chain of accountability was never established.

Current frameworks consider components within this chain independently. Zanni et al. (2022) identify the barriers to digital handover process flows but do not drill down to the tool level within each activity. Pishdad-Bozorgi et al. (2022) rate tools based on their fit for BIM-FM integration maturity but judge organizational readiness rather than task suitability. Sarkar and Majumder (2023) develop a challenges-to-capabilities matrix that is valuable for diagnosis but fails to provide actionable guidance on tool selection. Kopsida and Brilakis (2024) examine the readiness for digital twins, which is beyond the scope of handover, rather than the handover tasks that determine digital twin readiness. Notably, none of these frameworks offer the sequential reasoning grounded in task requirements necessary for a practitioner to ask: for this task, with this data need, what kind of tool is required, what capabilities should this tool possess, and how well do current options meet the task at hand?

2.6 Research Gap

The research gap is the absence of an integrated, activity-grounded, data-aware decision framework that translates the complexity of the construction-to-FM handover into a structured, usable evaluation instrument. This study is designed to fill that gap. The framework developed here does not begin with tools and ask what they can do; it begins with handover activities and asks what each activity demands in terms of information, responsibility, and tool capability and then holds the available market options accountable to those demands. In doing so, it provides a foundation for more consistent, evidence-based, and FM-aligned tool selection across the industry.

Industry teams lack a step-by-step operational roadmap that links specific site handover activities; snagging, testing and commissioning, documentation, and formal closeout, to the structured data requirements each activity generates, the tool capabilities required to manage that data, and an honest fitness assessment of available market options against those criteria.

CHAPTER-3: RESEARCH METHODOLOGY

The nature of the research problem within the domain of digital handover creates certain epistemological challenges. Specifically, on one hand, the area under study is highly data-driven, a construction project produces massive amounts of data, while on the other hand, the process of construction-to-FM digital handover is influenced by the professional practices of the participants, organisational cultures, contractual arrangements, and digital literacies that go beyond mere survey responses and statistical analyses. In order to understand the reasons behind failures to complete a digital handover, to explore how decisions related to selecting particular tools for this process are made, and to identify what practitioners need from the evaluation framework, a research approach was chosen that would be context-sensitive, nuanced, and reflective of real-world experiences.

The study adopts a mixed-methods research design - systematic literature study (secondary research) and semi structured interviews (primary research). Rather than viewing the issues associated with digital handovers as universally constant phenomena that can be studied using measurement and statistical generalization based on representative samples, the research acknowledges them as socially and contextually created phenomena, determined by the unique characteristics of each specific project and organization in terms of type of projects, organizational culture, relationships between contractual parties, and technological resources. Hence, the appropriate approach to such diversity of conditions implies using a methodological approach based on deep analysis, rather than broad generalization. The information obtained through interviews is considered a source of evidence that can be used for further coding and theming, allowing identifying generalizable patterns in the phenomenon under study.

3.1 Research Strategy

The research is structured in two sequential phases:

3.1.1 Systematic Literature Study

Phase one is a thorough review of academic literature, standards, and publications concerning the handover of projects from construction to facilities management, digital tool ecosystems, information management frameworks, and methods for evaluating tools. The scope of the review is constrained temporally and by theme, focusing specifically on literature published since 2021 and organized into five key themes: the lifecycle of the construction project and the role of the handover stage; information management frameworks such as ISO 19650, LOD, Data Drops, and Soft Landings; the transition from traditional paper-based processes to digital handovers; the openBIM ecosystem including IFC, COBie, IDS, BCF, and bSDD; and prior tool evaluation frameworks and their inherent limitations. Literature reviews act as secondary sources of data in their own right, providing a body of research into global issues, good practices, and recurring problems to compare against primary data collected through interviews.

3.1.2 Semi-Structured Interviews

Phase 2 will draw explicitly on the thematic framework created during Phase 1 and will entail the design, administration, analysis, and synthesis of semi-structured interviews with industry professionals. The selection of the technique of semi-structured interviewing is motivated by two factors. First, this method allows the opportunity to explore areas not initially planned to be considered, which becomes very crucial in such an area where practice deviates widely from the theoretical ideal presented in the literature. Secondly, there is enough structure present in this technique to allow for comparative analysis.

The interview guide is organised around the **research questions:**

RQ1: What digital tools are currently available in industry and what are their core conceptual capabilities regarding structured data management?

RQ2: How organizations currently select digital tools for the handover process?

RQ3: How can a conceptual framework be structured to effectively evaluate these digital tools to ensure they align with the project's long-term requirements?

Within this structure, each interview is tailored to the participant's specific professional context, commissioning agents are asked in depth about pre-commissioning data workflows; document controllers are interrogated on naming conventions and CDE configuration; FM academics are invited to reflect on the gap between pedagogical ideals and industry reality.

3.2 Sampling Strategy and Participant Selection

This research utilizes purposive sampling; a form of non-random sampling in which the respondents are chosen purposefully in relation to the topic of the study, rather than randomly. The use of purposive sampling for this particular study is justified as the number of professionals who have firsthand experience with digital handover is comparatively low and geographically localized. Using random sampling from a larger sample of construction workers would result in a disproportionately high percentage of people lacking experience in digital handover.

3.3 Target Participant Profiles

The target participants consist of individuals involved in the process in question either directly or firsthand in at least one of the following roles: digital delivery, coordination, and management; building information modeling coordination and management; FM software installation; document management and CDE management; project closing and commissioning. Six interviewees were selected, and these were their professions:

Table 3- 1: Primary research participants details

ID	Date	Mode	Role	Organization Type	Project Type
P1	08/02/26	Online	Facility Management assistant faculty	Private University	-
P2	10/02/26	In-person	BIM Manager	Founder (BIM consulting firm)	Residential, Mixed-use, commercial
P3	05/03/26	Online	VDC manager	MNC (Tier-1 construction firm)	High end govt. and private construction projects
P4	08/04/26	Online	Document controller	MNC (Tier-1 construction firm)	High end govt. and private construction projects
P5	08/04/26	Online	Project Manager	Real estate construction company	Government and Private projects
P6	27/03/26	Online	Specialized FM software vendor	Private software company	High end govt. and private construction projects

3.4 Data Analysis Approach

The transcription of the interviews was subject to analysis through thematic analysis. This involved carrying out thematic analysis through Braun & Clarke's (2006) six phases: familiarization with the data, initial coding of data, searching for themes, theme review, defining and naming themes, and finally writing up.

Three major themes have emerged from this process; BIM adoption trends and the implications on choice of tools; the range of approaches used to carry out handovers; and the range of digital tools used for carrying out construction projects. These three themes are presented fully in chapter four together with the findings from the literature review presented in chapter five.

3.5 Ethical Considerations and Anonymity

To ensure the protection of the participants and to encourage candid disclosure regarding sensitive project data and industry barriers, all research participants were granted strict anonymity. Before the interviews, participants were informed of the study's purpose and gave their consent. To maintain confidentiality, all identifiable information including individual names and specific company names was redacted. Instead, participants are referred using alphanumeric identifiers (P1, P2, etc.), and their organizations are categorized by sector and scale rather than by name.

.

CHAPTER-4: DATA COLLECTION

4.1 Secondary Data: Literature Study Findings

4.1.1 Digital Environment in Handover Phase

A vast variety of digital applications have emerged in FM to become tools, integrated tools, platforms and integrated ecosystems that deliver data in an organized and interoperable way, throughout the life cycle of FM applications. Those applications are not only enabling data sharing but integration between different FM systems and stakeholders. They were linked to each other within digital ecosystems for improved decision-making. (Otranto et al. 2025) There is a transition from digital tools to digital ecosystem; this represents an increase in the integration of applications and the creation of linked environments in which data can flow through the whole project life cycle, between stakeholders and applications. Initially, applications are simple **standalone tools**, then they evolve into **data exchange suites** among multiple applications. Subsequently, with more interoperability, systems are interconnected through the help of common standards, eventually, forming **digital ecosystems** where the data stream could be continuously transferred. (Chatsuwan, Moriwaki, et al. 2025)

4.1.2 Digital Tools used in handover activities

The following section presents the digital tool inventory for each handover activity as augmented by critical insights drawn from post-2021 literature findings. For each tool, a critical insight is also appended.

a) Testing and Commissioning Activity

1) Field Management & Asset Platforms - Autodesk Build (formerly BIM 360) and Procore

Tools like Autodesk Build and Procore allow commissioning agents to use mobile devices on-site to complete digital checklists. These tools link specific test results directly to an asset's digital twin or COBie data row, ensuring that when a pump is tested, its warranty and manual are already digitally attached (Pishdad-Bozorgi et al., 2022).

Critical Insight: Whereas both Autodesk Build and Procore provide extensive support for linking tests to assets, it is clear from Otranto et al. (2025) that the effectiveness of this linking process depends entirely on the quality of the asset database. In cases where the COBie component sheet is incomplete or no ID numbers have been assigned to pieces of equipment during the construction process, the commissioning agent ends up linking the test results to a fictional asset at best. According to Sarkar & Majumder (2023), commissioning data collected is often found to be recorded in a format which makes exporting to CAFM/CMMS impossible, thus causing the same issues the tool was designed to solve.

2) Purpose-Built Commissioning Management – CxAlloy

CxAlloy is a specialised commissioning management platform that structures functional performance test plans, multi-party sign-off workflows, and test record archiving. It is widely regarded in the literature as purpose-built for commissioning workflows, with direct COBie data export capability (Pishdad-Bozorgi et al., 2022).

Critical Insight: Chatsuwan, Ichinose, and Alkhalaf (2025) point out that bespoke commissioning software encounters an increasing adoption challenge in the context of a market where BIM coordination still falls short of LOD 400 in its construction stage. Where the model components against which CxAlloy's commissioning procedures are based lack validated equipment identifiers and proper spatial relations, the commissioning data set becomes a stranded resource rather than an integrated asset entry. The complexity of the tool implies a tacit prerequisite for a data-enabled project setting, one which, according to the P3 interview, fails to materialize in the overwhelming number of existing handovers.

3) IoT-Enabled Sensors & Data Loggers

Modern commissioning utilises Internet-of-Things (IoT) sensors to monitor real-time building performance during functional testing. These sensors provide empirical data on air quality, temperature, and energy loads, fed into a CDE to validate that the building meets its design intent (Sarkar & Majumder, 2023).

Critical Insight: The retention of IoT sensors data to support FM operations constitutes one of the least investigated areas of vulnerability in the digital handover process according to Ichendu & Irimiagha (2024). Data collected by IoT sensors throughout the process of commissioning is normally channeled into a testing facility or CDE up until the completion of the commissioning phase; however, there is rarely continuity or institutionalization of the data transfer process beyond the end of the testing phase. What often happens, consequently, is that any baseline performance data generated from the commissioning phase which represents the closest approximation to the real conditions in which the building operates becomes increasingly unavailable to FM personnel a few months after handover.

4) Digital Twins & AR/VR Tools

Digital Twins act as live repositories for testing and commissioning data. During handover, Augmented Reality tools can be used by FM teams to view commissioning data overlaid on physical assets, facilitating knowledge transfer (Autodesk, 2024).

Critical Insight: As pointed out by Kopsida and Brilakis (2024), the implementation of the Digital Twin requires the creation of a LOD 500 as-built verified model, an approach that is confirmed to be difficult to realize in reality according to Chatsuwan et al. (2025). Moreover, Khan et al. (2024) highlight that the use of AR/VR technologies poses significant difficulties for adoption due to their complex nature, especially for facility management teams that have had no role in BIM during construction phases. Indeed, no single respondent mentioned having implemented a Digital Twin in his/her professional practice.

b) Snagging

1) Mobile Defect Management Application - Novade

Novade enables on-site teams to capture defects using smartphones or tablets, providing real-time updates and direct reporting channels to subcontractors (Hashim et al., 2024).

Critical Insight: Hashim et al. (2024) identify a persistent structural limitation in mobile defect management applications: defect data captured on-site is frequently not linked to BIM model elements, meaning that the aggregated defect record cannot be spatially interrogated or associated with an asset's lifecycle history in the AIM. The defect is logged and closed, but the fact of its occurrence leaves no trace in the asset's digital record. Zanni et al. (2022) reinforce this, noting that mobile snagging tools create large repositories of photographic and textual defect data that exist as structurally isolated archives, disconnected from the coordinated data environment that should inform FM planning and preventive maintenance scheduling.

2) Photo and Video Documentation - Openspace

Openspace allows users to attach timestamped, geo-tagged visual evidence to a specific pin on a 2D plan or 3D BIM model, creating a spatially indexed photographic record of site conditions (Hashim et al., 2024).

Critical Insight: While Openspace's spatial indexing capability addresses the location-linking gap identified in simpler defect tools, Sarkar and Majumder (2023) observe that photo-documentation platforms generate large volumes of unstructured visual data that are rarely integrated into the project's CDE with the document status metadata required by ISO 19650. The photographs exist as evidence, but they do not function as information within the project's governed data environment. Otranto et al. (2025) note that the absence of a standardised taxonomy for associating photographic records with model elements means that Openspace's spatial referencing is only as reliable as the accuracy of the underlying BIM geometry, which in snagging contexts is frequently incomplete.

3) Automated Workflow and Notifications - Procore Punch List Tool

Procore's Punch List tool automatically notifies the responsible subcontractor upon defect identification and tracks rectification status through to final verification (Hashim et al., 2024). **Critical Insight:** Ichendu and Irimiagha (2024) document a structural dependency that significantly limits the effectiveness of automated notification workflows: their reliability is entirely contingent on all responsible subcontractors being onboarded to the platform with active user accounts and reliable connectivity. On projects where specialist subcontractors are small firms with limited digital infrastructure, the notification workflow degrades to manual follow-up, negating the tool's primary efficiency claim. P3's description of traditional snagging conducted with printed plans is not an anomaly; it reflects the downstream consequence of a supply chain whose digital readiness does not match the platform's operational assumptions.

4) Aggregated Defect Analytics - Autodesk Build

Autodesk Build can aggregate defect data to identify recurring patterns or root causes, enabling developers to improve quality control in future projects (Hashim et al., 2024).
Critical Insight: Ichendu and Irimiagha (2024) establish that aggregated defect analytics of the kind offered by Autodesk Build are only analytically valid if defect entries are tagged consistently using a pre-defined, project-wide taxonomy. In practice, defect classification is left to individual site operatives who apply inconsistent terminology, rendering pattern analysis statistically unreliable. The analytical capability exists at the platform level, but the data governance conditions required to activate it; a defined defect taxonomy, enforced at the point of entry; are rarely established at project outset. This is a direct instance of the data-before-tool principle: the tool's most distinctive feature cannot be used without data quality decisions made before the tool is deployed.

c) Documentation Handover

1) CDEs with Version Control - ACC and Bentley ProjectWise

CDEs like ACC and Bentley ProjectWise serve as the single source of truth for all project information, managing document status workflows according to ISO 19650 standards and preventing the information fragmentation that typically occurs during the construction-to-FM transition (Senthilvel et al., 2022).

Critical Insight: The naming convention is either provided by the client (which presupposes a client sophisticated enough to have one) or improvised by the BIM team mid-project, at which point a portion of the archive has already been submitted under an incompatible schema. Senthilvel et al. (2022) confirm that this is not an edge case it is the modal condition of CDE deployment on projects without a formally authored BIM Execution Plan established at contract award. The CDE is a governance instrument, not a filing system; its value is created before the first document is uploaded, not after.

2) Automated COBie and Metadata Validation - Solibri Office

Solibri Office uses algorithms to scan handover files, including IFC models and COBie spreadsheets, to ensure they are not missing critical FM data such as warranty end dates or manufacturer details (Patacas et al., 2023).

Critical Insight: Otranto et al. (2025) identify a recurring and counterintuitive failure pattern: automated validation tools like Solibri are deployed at the point of submission, after the data has already been compiled, meaning that validation failures require retroactive correction by supply chain members who have already demobilised or whose contractual obligations have technically concluded. Patacas et al. (2023) argue that validation must be embedded as a continuous process throughout data production, not a terminal quality gate. More critically, the interview evidence suggests that COBie validation tools are rarely deployed at all in current practice because project teams have not been trained to interpret and act on validation outputs; the tool is purchased, the licence is active, and the software sits unused because the human process to support it was never designed.

3) Asset Information Requirements (AIR) Management Platform - GliderBIM

GliderBIM allows the project owner to define precisely what data they need at the project outset. During handover, the tool tracks the completeness of these information requirements in real time (Cavka et al., 2023).

Critical Insight: The operational logic of AIR management platforms is entirely dependent on the AIR having been formally defined and contractually embedded at project initiation; a prerequisite that Cavka et al. (2023) acknowledge is absent in a large proportion of current projects. Where the AIR has not been defined, the platform has no requirements to track and effectively functions as an expensive document register. Ichendu and Irimiagha (2024) frame this as a governance sequencing failure: tools designed for requirements management cannot compensate for the absence of a requirements definition process, they can only make that absence visible in real time, which provides accountability without resolution.

4) Electronic Document Management System - Aconex

Aconex is an EDMS used for structured document submission, transmission, and archiving on large-scale projects. It provides a centralised library for the project lifecycle, with each document assigned a unique code, revision number, and submission date (P4, direct interview testimony).

Critical Insight (Practitioner-Grounded): P4's direct account establishes the most consequential operational limitation of EDMS platforms in current practice: the PMIS standard the naming convention and document classification schema is either provided by the client at contract award or constructed ad hoc by the BIM team after project commencement. In the absence of a pre-defined standard, the CDE's searchability degrades progressively as more documents are submitted under inconsistent naming conventions. Sarkar and Majumder (2023) position this as an organisational rather than a technological failure: the platform supports governance, but it cannot enforce it. The practical implication is that an Aconex-hosted archive may be formally complete every document has been submitted while being practically inaccessible to an FM team searching for a specific system's commissioning records two years after handover.

d) Formal Handover

1) Handover Management and Digital Building Manual Platform - Activeplan

Activeplan replaces traditional physical O&M manuals with cloud-based, interactive digital building manuals, linking every physical asset to its specific digital data including manuals, warranties, and maintenance schedules (Pishdad-Bozorgi et al., 2022).

Critical Insight: Pishdad-Bozorgi et al. (2022) acknowledge that digital O&M platforms are only as useful as the asset data linked within them a principle that maps directly onto the garbage-in-garbage-out dynamic that characterises handovers where asset registers are incomplete. If a boiler has been commissioned but its warranty certificate was submitted as a scanned PDF without an asset ID or equipment classification tag, the Activeplan entry for that asset will be a structural placeholder with no actionable data behind it. Sarkar and Majumder (2023) document this as the most common failure mode of handover management platforms: the digital manual is created, the assets are listed, and the FM team discovers during the defect's liability period that the majority of linked records are either empty, incorrect, or refer to superseded equipment specifications.

2) **Digital Twin & Asset Information Model Platforms - Autodesk Tandem and Bentley iTwin**

Autodesk Tandem and Bentley iTwin create virtual building representations populated with the structured data gathered during construction. Unlike design BIM models, these platforms are optimised for owner operational use and are intended to maintain the digital thread post-handover (Senthilvel et al., 2022).

Critical Insight: Kopsida and Brilakis (2024) establish through systematic evaluation that Digital Twin readiness requires not merely an LOD 500 model, but a verified, field-reconciled model in which every data attribute has been confirmed against the installed condition a standard that Chatsuwan et al. (2025) report is rarely achieved in practice, even on BIM-mature projects. Senthilvel et al. (2022) warn that Digital Twin platforms loaded with unvalidated as-built data do not preserve the digital thread they formalise its degradation by creating a persistent record of inaccurate asset information that FM teams may rely on for maintenance decisions for decades.

3) **Data Integration and Middleware Tool - EcoDomus**

EcoDomus functions as a middleware layer that pushes data from the CDE into the owner's FM software (CMMS or IWMS), automating the transfer of COBie and IFC data into operational systems (Patacas et al., 2023).

Critical Insight: Patacas et al. (2023) argue that automated middleware tools represent the highest-leverage point in the handover data chain and also its most fragile link. Middleware can automate the transfer of structured, correctly classified data; it cannot repair or restructure data that was never properly formed. If the COBie sheet arriving from the CDE has empty required fields, incorrect classification codes, or asset IDs that do not match the CMMS asset register, EcoDomus will execute the transfer faithfully and populate the FM system with the same errors at scale. The tool amplifies whatever data quality exists at the source. Ichendu and Irimiagha (2024) observe that this amplification effect means that organisations which deploy middleware without first validating source data often find that their CMMS is more comprehensively wrong after the automated import than it would have been if the data had been entered manually, with a human operator filtering obvious errors.

4.2 Primary Data: Semi Structured Interview Findings

A total of six semi-structured interviews were conducted with industry professionals involved in the construction industry. The interviews aimed to capture practical insights on existing processes, challenges, and the use of digital tools. Participants were selected from diverse backgrounds working in or related to project handover phase and facility management integration.

4.2.1 Thematic Data Collection of Semi Structured Interviews

Theme 1: BIM Maturity

P1, P3, P5 reported that in India, BIM adoption is only seen till 5D (Cost estimation) majorly. BIM adoption is still considered only for 3D modelling purpose and for presentation. In big industrial and infrastructure projects, ACC is massively being used as CDE. In small scale projects, data like approvals, commissioning reports, etc. in handover process is transferred through gmail and whatsapp in pdf, dwg, skp formats along with submitting hardcopies of the same, because the access to these new technologies is not affordable to them.

P2, P4 reported BIM adoption is seen till 7D (Facility management) in other regions like UAE where it is getting adopted massively and rapidly along with other technologies like digital twin.

Theme 2: Handover Modalities

P2, P4 reported three ways of doing handover activities first one being the old way where while performing testing and commissioning or snagging activity, people used to carry printouts in hands and mark the incomplete works manually on 2D printed plans, second being a little more advanced where people take pictures of the systems installed having bar codes on it which when scanned give detailed information of the systems installed to do the testing and commissioning activity and lastly where third party is appointed to do all the handover activities so that they will populate the digital tools on their own according to them which is not done by everyone as it gets costly. These third-party consultants might have their own software or might have licensed the one which is available in market according to the client.

P6 reported working with a Facility Management software platform that serves as a leading solution in the domains of IWMS, CAFM, and FMS. The system also addresses aspects related to environmental sustainability, health, and well-being within smart or autonomous buildings. It is a modern, integrated solution that enables organizations to gain a comprehensive view of facility operations by consolidating information related to space, occupants, assets, and maintenance within a single unified platform. Their involvement in the project (like from initiation of project or after construction completion) is completely based on client requirements.

P1, P5 reported if it’s a government project then after getting all the approvals, they need to be uploaded on the online government portal which acts as a central database and can be accessed from there by all the required and authorized stakeholders of the project.

Theme 3: Tool Landscape

P4 reported that, they have worked as a Document Controller on a Saudi-based project. Their main responsibility was maintaining digital documentation for the entire project, which is a key part of information management. Using an Electronic Document Management System like Aconex, they submitted drawings and project-related documents. These were then automatically accessible to the relevant project team members, while also being stored to create a centralized library for the entire project lifecycle. Each document was required to have a unique document code, along with a revision number and date. Before submitting documents on Aconex, they carefully checked all details such as document numbers, revision numbers, submission dates, and other relevant information to ensure accuracy and consistency. In Aconex, major challenge is fixing the PMIS standards, either client should share their standard documents naming conventions or you have to create and fix one with help of BIM team or BIM specialist. Other tools like Aconex as far as they know are sharepoint, asite and viewpoint.

Through careful thematic analysis of the six semi-structured interviews, it is understood that all three core themes emerged consistently across multiple participants rather than isolated perspectives. Theme 1 (BIM Maturity) clearly differentiated regional practices, with P1, P3, and P5 describing India's characteristic 5D in use while P2 and P4 detailed other regions mandated 7D integration requirements. Theme 2 (Handover Modalities) mapped cleanly onto practitioner experiences, as P2 and P4 articulated platform-driven workflows, P1 and P5 relied on manual paper-based processes, and P3 with P6 navigated hybrid transitions. Theme 3 (Tool Landscape) demonstrated complete saturation, with every participant independently identifying vendor influence as overriding data compatibility in tool selection decisions. These patterns, detailed in Appendix 4, validate the themes' robustness and directly informed framework development.

CHAPTER-5: DATA ANALYSIS AND RESULTS

The following chapter discusses the findings synthesized from the two phases of the study, namely, the systematic literature review and the semi-structured interviews conducted with six practitioners. The analysis is strategically presented in a specific order, beginning from qualitative insights at an individual level, then developing into themes among participants, and finally resulting in the development of the main research deliverable known as the Construction-to-FM Handover Tool Evaluation Framework. Each part of this chapter corresponds to one stage in this process, culminating in an actual tool rather than a perfect theoretical concept.

5.1 Analysis of Secondary Data (Literature Study)

The systematic literature review established four analytically productive findings that directly shaped the framework design.

5.1.1 Data Quality as the Governing Variable of Tool Performance

Without question, the most consistent result in the post-2021 literature is that the effectiveness of any FM digital tool is inevitably limited by the quality and comprehensiveness of the information it gets at the handover stage. It is not an incidental discovery but rather a structural phenomenon that accounts for why businesses spend on cutting-edge technology and still underutilise it. The authors Zanni et al. (2022) reveal this problem as a bottleneck in the process dimension; Pishdad-Bozorgi et al. (2022) highlight it as an issue of organizational maturity; Sarkar and Majumder (2023) illustrate it as a gap between challenges and capabilities; and Kopsida and Brilakis (2024) conceptualize it as a deficiency in digital twin readiness. In each case, the insight remains the same: tools are data-driven devices, and the handover data chain is dysfunctional.

There is a direct implication for the framework here. If an assessment of tools starts off by focusing on software features without considering the data situation first, then the wrong variable is being assessed. It is precisely why Information Need & Responsibility stage was considered when developing the framework for this study.

5.1.2 The openBIM Ecosystem: Promise and Implementation Gap

In the literature, the authors discuss an openBIM ecosystem, which is highly advanced in its theoretical underpinnings. The IFC serves as a format for exchanging geometric information and data. COBie is used for the exchange of asset data in FM systems. IDS is used to automate checking whether the required properties have been specified. BCF provides means of communication for recording issues. bSDD acts as the semantic dictionary.
In theory, the above ecosystem is capable of facilitating seamless lossless information flow from the construction phase to the FM system. In practice, however, poor quality of IFC files exported by various software, presence of empty cells and errors in classification schemes of COBie sheets at handover time, as well as lack of proper use of validation functions provided by software such as Solibri Office due to insufficient training of project teams are among common problems in BIM processes (Otranto et al., 2025; Chatsuwan et al., 2025). This problem helps set up one of the criteria to be embedded into the framework at the Stage. The criterion requires that the selected tool should not just support IFC it should produce validated IFC.

5.1.3 The Fragmented Tool Landscape

The literature reveals that there exists a situation where no single tool covers all the activities involved in the process, and the dominant tools in each category of activity (commissioning management, snagging, document management, and formal handover) do not have the same level of interoperability between themselves and other FM software solutions. Such a fragmented situation cannot be accidental since the nature of the handover process involves several activities involving multiple stakeholders, none of which has been successfully incorporated by a vendor into one single system.

This observation is relevant to the framework presented in that the tool assessment process should be done based on an activity-by-activity approach and not from a platform point of view. This explains why Stages A and B of the framework define the handover phase and its activities as the unit of analysis.

5.1.4 Gaps in Existing Evaluation Frameworks

A critical review of the four most relevant frameworks after 2021 reveals that while each has made an important contribution, none offers the practitioner the necessary logic by which to determine which tools to use when translating the handover requirements at an activity level into practice. The reason why this gap exists is not that the criteria that need to be considered in order to guide the decision-making process are too sophisticated. Interoperability, owner-centricity, and data integrity are correctly described as the three important pillars to consider, but there lacks a logical sequence on how to use them.

5.2 Analysis of Primary Data (Semi-Structured Interview)

Data gathered from the six semi-structured interviews proved to be highly contextual and informative, confirming some findings in the existing literature while contradicting others. Thematic analysis resulted in three core themes, which directly influenced framework design.

5.2.1 Theme 1: BIM Adoption - A Geography of Maturity

Participants P1 and P2 have pointed out a significant difference between the use of BIM in India compared to its application in developed countries, like the United Arab Emirates. In India, the implementation of BIM technology occurs mainly in relation to 3D coordination and, in large-scale projects, cost estimation, i.e., 5D. The use of BIM technology as a means of handling information on the 6D and 7D levels, which include sustainability analysis and FM, is a far-fetched notion in the Indian environment. Email and messaging applications, such as WhatsApp, are used to exchange unstructured data (PDF, DWG, SKP files) along with paper versions in small and mid-sized projects.

This map of maturity implies differences in the set of evaluation criteria when selecting tools for an advanced-maturity context (when the use of IFC and COBie becomes obligatory and use of CDE in the supply chain) compared to a transitional maturity context (the focus should be on structured data capture).

This is possible by providing for an evaluation of the fitness of the instrument, which can be done depending on whether the tool has been evaluated to partially fit; and in a maturity advanced situation, it can be fully fit.

5.2.2 Theme 2: Three Modalities of Handover Execution

The participant P3, relying on his experience working for a Tier-1 multinational contractor, outlined three different approaches used in executing handover activities:

- The traditional approach, where commissioning and snagging are performed using paper-based plans, while the defects and test results are manually noted before being entered into digital systems, if ever.

- The mixed approach, wherein there is a barcode or QR code on the installed equipment. When the code is scanned using a smartphone, it fetches the information about the assets. The process minimizes the amount of manual entry required but still relies heavily on it. The quality of asset data in the barcode is only as good as the asset data model created during the construction process.
- The delegated approach, where a third-party consultant will manage the whole process of data capture and handover. It involves populating digital systems, validation of COBie output, and handover to FM systems. While the results produced through this approach can be of high quality, it is relatively costly. Moreover, the platform preferences of the consultant do not always match the owner's FM systems architecture.

This three-modality characterisation has a direct bearing on the framework's stage of Tool Type Needed and stage of Selection Criteria. Different modalities make different demands on tool capability: the traditional modality demands tools with strong mobile data capture and offline functionality; the hybrid modality demands tools with asset register integration and barcode/QR linking; the delegated modality demands tools with robust data export capabilities and open API connectivity to FM platforms. The framework's selection criteria are calibrated to make these distinctions explicit.

5.2.3 Theme 3: The Digital Tool Landscape as Practitioners Experience It

Participants P4 and P6 provided the most granular operational insight into how digital tools function and fail in practice. P4's account of document control on a Saudi-based project using Aconex illustrated the critical importance of PMIS standards: without a pre-agreed document naming convention, an Electronic Document Management System becomes a liability rather than an asset, producing a CDE that is formally compliant but practically unsearchable. P6's account of an integrated FM platform spanning IWMS, CAFM, and FMS functions demonstrated the potential of a fully integrated operational tool but also the challenge of onboarding an organisation that has not prepared its data architecture during construction to receive the output of such a system. P5's account of government project protocols in which all approvals are uploaded to a centralised government portal that functions as a statutory CDE illustrated a third mode of tool deployment driven not by organisational preference but by regulatory mandate.

This finding highlights the importance of the framework's Stage of Market Options and Stage of Fit Assessment accounting not only for functional capability but for regulatory compatibility.

5.3 Cross-Synthesis: Divergent Findings

As illustrated in Appendix 3 below, there is an elaborate and comprehensive juxtaposition of claims made by literature since 2021 against the realities experienced by practitioners as articulated during the interviews done in preparation for this study. The rows in the table below capture the theory or model as found in literature, its associated standards, evidence from the practitioner's perspective that contradicts literature on the matter, the participant and sources associated with such evidence, and the interpretation of the differences. It should be noted that the differences highlighted here are not meant as criticisms of the inadequacy of practitioner practice or repetition of the literature.

The eight differences mapped across theories/concepts are:

1. Structured Data Delivery via COBie
2. BIM as a Lifecycle Data Management Tool (6D/7D)
3. CDE as the Centralised Single Source of Truth
4. Systematic, Criteria-Based Tool Selection
5. Early FM Stakeholder Involvement
6. openBIM Interoperability (IFC/COBie) as Functional Reality
7. Handover Modality: Digital-First Workflow
8. Digital Twins as FM Operational Tools

As a whole, the eight differences presented in Appendix 3 indicate the existence of a set of underlying assumptions within post-2021 research into digital handovers that are not applicable in all cases. This means that although the theory may be right, it can be argued that there exists some geographical and organisational limitation to it in the sense that not all markets have reached the same level of market maturity and that all organisations are equally prepared to undertake their respective digital handovers. The use of a framework meant for a 7D BIM in the UAE is not simply one for scaling the Indian handover process – it is inherently a different framework altogether.

5.4 Cross-Synthesis: Convergent Findings and Framework Drivers

Both the literature and interviews have revealed five structural findings that immediately guide the development of the Tool Evaluation Framework:

- Handover is an activity, not an event: Tool selection depends on accurate mapping of the individual activities within the handover process, together with their individual information needs, not just a general assessment of "handover capability."

- Data comes before tool selection: Any tool selection or evaluation should first and foremost start with a pre-assessment of the data context - more precisely with determining whether the incoming data is complete, structured, and machine-readable.
- Responsible parties must be determined: Information gaps in handover processes are not a matter of luck; they are a predictable outcome of lack of clarity concerning responsibilities at the initial stages of the project. The evaluation framework should incorporate mapping of responsibilities in the analysis.
- Criteria must be activity-dependent: A set of requirements for a tool to facilitate commissioning management cannot be the same as requirements for a tool performing a handover management or COBie validation task. Generic criteria lead to generic assessments that are bound to be misleading.
- Fit Assessment Needs to Be Honest and Nuanced: A yes/no approach for whether or not a piece of software supports IFC will not suffice. A more refined fit assessment (Fully Fit/Partially Fit/Poorly Fit) is needed.

5.5 The Construction-to-FM Handover Tool Evaluation Framework

Key output of this research is the Construction-to-FM Handover Tool Evaluation Framework, a nine-step decision-making hierarchy that allows for the progression from identifying handover phases all the way to assessing market fitness. In contrast to common approaches of evaluating software products by considering their features first as listed by a software provider, this particular framework starts from activity and data.

5.5.1 Framework Architecture: Nine Stages

The framework is structured as a progressive analytical sequence. Each stage builds on the outputs of the previous, ensuring that the final assessment is the product of a rigorous chain of reasoning rather than an intuitive judgement.

Table 5- 1: The Nine-Stage Tool Evaluation Framework Architecture

Stage	Name	Description and Analytical Function
A	**Handover-Oriented Lifecycle Phase**	Identifies which phase of the handover lifecycle (Testing & Commissioning, Snagging, Documentation Handover, Formal Closeout) is under analysis. This establishes the primary context for all subsequent stages and ensures that the evaluation is phase-specific rather than generic.

Stage	Name	Description and Analytical Function
B	**Process within the Phase**	Identifies the specific process occurring within the lifecycle phase for example, Pre-Commissioning Checks or Formal System Testing and Witnessing. This sub-phase specificity is essential because different processes within the same lifecycle phase may require entirely different tool capabilities.
C	**Activity Description**	Describes what actually happens during the process the specific site-level and administrative activities involved. This grounds the analysis in the operational reality of the handover, moving from abstract phase description to concrete activity characterisation.
D	**Information Need and Responsibility**	Identifies three sub-elements: (i) what information is needed for this activity, (ii) who creates or provides that information, and (iii) who checks it and receives it. This stage is the analytical heart of the framework, as it is the point at which data quality and responsibility clarity the two root causes of handover failure are made explicit.
E	**Tool Type Needed**	Identifies the category of digital tool required to support the mentioned activities for example, Field Management & Asset Commissioning Platform, CDE with COBie Validation, or Handover Management Platform. Tool type categorisation enables generic evaluation criteria to be applied consistently across different activities.
F	**Market Options**	Identifies the digital tools currently available in the market that claim to support the identified tool type and activities.
G	**Selection Criteria**	Defines the specific functional requirements that a tool of the identified type must satisfy to genuinely support this activity. Criteria are grounded in the four pillars of the research aim: **data quality** (can the tool ingest, validate, and structure the required information?), **safety** (does it protect data integrity and access?), **scalability** (can it grow with the project and portfolio?), and **productivity impact** (does it reduce manual effort and information loss?). These four pillars are then separated into

Stage	Name	Description and Analytical Function
		mandatory and desirable tiers based on the needs of the project or clients
H	**Fit Assessment**	Applies the Stage G criteria to each Stage F market option, producing a graded fitness assessment: a tool "Fully Fits" if it satisfies all mandatory criteria and at least 50% of desirable ones; "Partially Fits" if it satisfies all mandatory but desirable criteria are unmet; "Poorly Fits" if any mandatory criterion is unmet. This graded assessment enables practitioners to make transparent, evidence-based selection decisions.
I	**Pricing**	If more than one option of tools gets identified after Stage H, then costing will be last assessment used for making the decision.

5.5.2 Framework Design Principles

The framework is designed around four principles that distinguish it from existing evaluation models:

- **Activity-First Logic:** The framework begins with the handover activity, not the tool. This inversion relative to conventional software evaluation practice ensures that selection decisions are driven by operational need rather than vendor influence or familiarity bias.
- **Data-Before-Tool:** Stage D (Information Need and Responsibility) precedes Stage E (Tool Type Needed) because no tool assessment is meaningful without a prior characterisation of the data context. Tools that cannot ingest the available data, or that cannot validate and structure it for FM use, will fail regardless of their feature set.
- **Responsibility Explicitness:** The framework maps who creates and who receives each piece of information, making the accountability chain visible. This transparency is designed to prevent the diffusion of responsibility that characterises many handover failures, where critical data is absent because no one was clearly assigned to produce it.
- **Graded and Contextual Fitness:** The Stage H fitness assessment is deliberately graded, and is intended to be applied contextually; a tool's fitness rating may differ across project types, organisational maturity levels, and geographic markets. This contextual sensitivity is a direct response to the interview finding that the tool landscape looks very different in a BIM-mature market in other regions like the UAE compared to the transitional landscape in India.

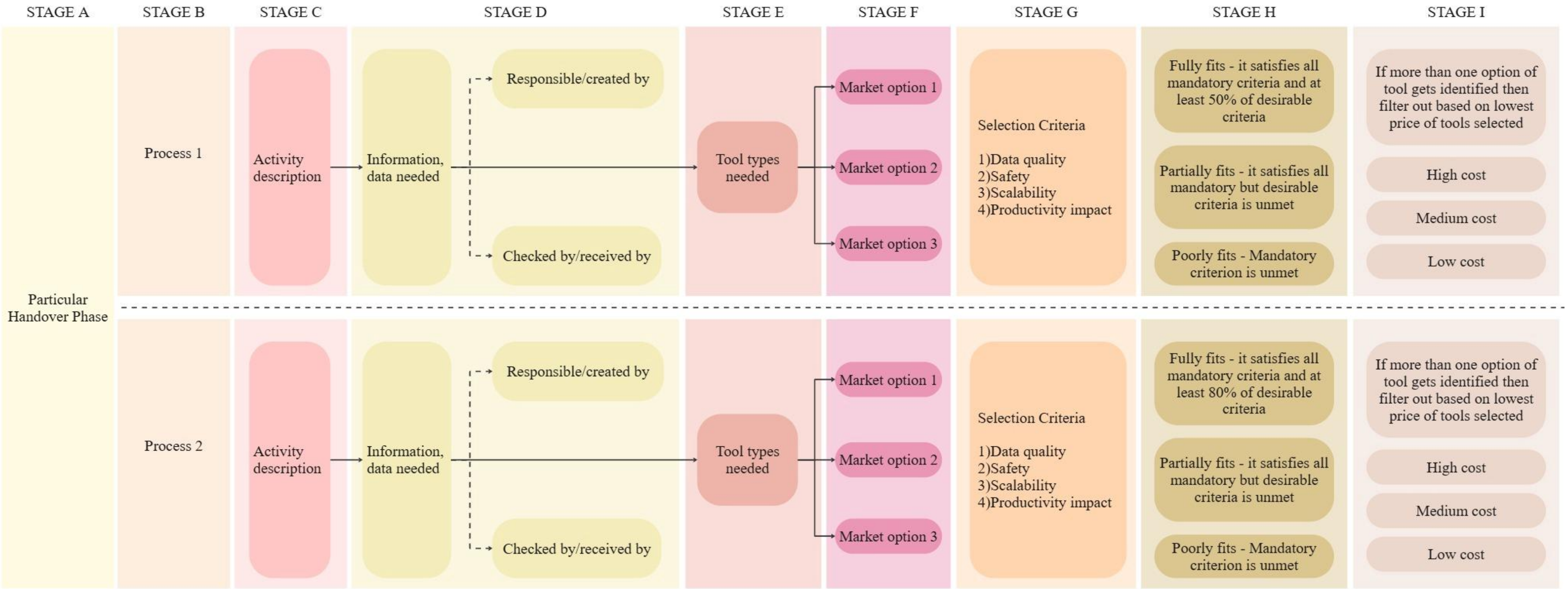

Figure 5-1: Flowchart of conceptual evaluation framework of digital tools

5.5.3 Illustrative Framework Application

To demonstrate the operational logic of the framework, the following example traces a single handover activity of Testing and commissioning through all eight stages:

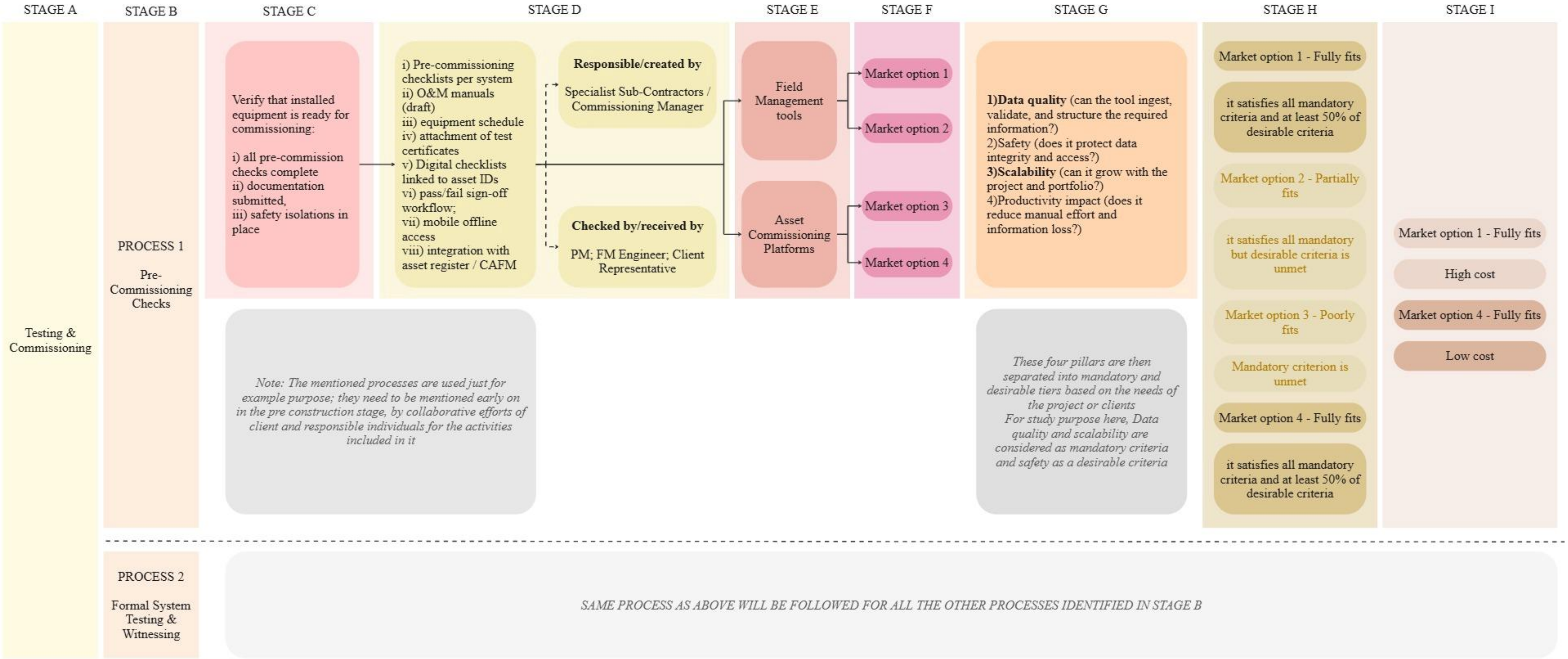

Figure 5-2: Illustrative Framework Application

5.5.4 Framework Significance and Implications

The Construction-to-FM Handover Tool Evaluation Framework represents a meaningful advance over existing approaches in three respects. First, it operationalises evaluation at the activity level the grain at which tool fitness can be practically assessed rather than the organisational or platform level at which most existing frameworks operate. Second, it embeds data quality and responsibility mapping as prerequisites for tool evaluation, addressing the root causes of handover failure rather than their symptomatic expressions. Third, it produces a graded and contextual fitness assessment that is honest about the limitations of available tools, enabling practitioners to make informed trade-off decisions rather than defaulting to the platform with the most compelling vendor demonstration.

For the industry, the framework provides a replicable, scalable decision-support instrument that can be adapted to different project types, organisational contexts, and market maturity levels.

Most importantly, for the building owner and FM team who will operate an asset for decades after the contractor has left the site, the framework offers something the industry has not previously provided: a structured, evidence-based rationale for choosing the tools that will determine whether the information accumulated during construction is preserved, organised, and genuinely useful or whether it is lost, as it has so often been before.

CHAPTER-6: CONCLUSION

The research set out with a clearly defined aim: to develop a tool-evaluation framework that would enable construction and Facility Management (FM) organizations to assess digital tools for the handover phase, grounded not in vendor capability claims but in the operational realities of data quality, safety, scalability, and productivity impact. The challenge at the heart of this inquiry was not simply technological in nature. The industry has produced sophisticated digital tools, open standards, and information management frameworks in considerable abundance; what it has consistently failed to produce is a structured, practitioner-facing method for aligning those tools with the specific data demands of individual handover activities. This research addressed that structural absence through a two-phase mixed-methods design, combining a systematic literature review with six semi-structured practitioner interviews, and ultimately delivering the Construction-to-FM Handover Tool Evaluation Framework as its primary scholarly and professional contribution.

Achievement of Research Objectives

The first objective investigated how handover data quality and structured formats affect the performance and usability of FM digital tools. This objective was addressed comprehensively through the critical appraisal of information management frameworks including ISO 19650, the Level of Development (LOD) framework, structured Data Drops, and the openBIM ecosystem comprising IFC, COBie, IDS, BCF, and bSDD. The convergent evidence drawn from both the literature and practitioner interviews establishes a consistent and consequential conclusion: digital tools are inherently data-dependent systems, and their capacity to support asset tracking, maintenance planning, and facility operations is determined entirely by the completeness, structure, and machine-readability of the information delivered at handover. This objective is fully achieved, establishing data quality as the foundational variable around which all subsequent stages of the proposed framework were designed.

The second objective sought to investigate how contractors and FM teams currently select digital tools for handover workflows. This was addressed through semi-structured interviews and thematic analysis, which revealed that tool selection in current industry practice is rarely systematic. Decisions are frequently driven by familiarity, vendor influence, cost constraints, or reactive project requirements, rather than by a structured assessment of data readiness or activity-specific functional requirements. Participant accounts illustrated how even sophisticated platforms become practically dysfunctional without pre-agreed naming conventions, while testimonies highlighted the gap between the potential of fully integrated FM platforms and the data architecture needed to receive them. These empirical findings directly informed the framework's emphasis on activity-first evaluation logic and contextual fitness assessment, ensuring that the proposed instrument corrects the very gaps that current practice exposes. This objective is achieved, providing an evidence-grounded critique of existing selection practices that motivates the necessity of the proposed framework.

The third objective was to identify and categorize the essential digital tools currently utilized in the handover phase. This was fulfilled through comprehensive mapping of the digital tool landscape across all four primary handover activities: Testing and Commissioning, Snagging, Documentation Handover, and Formal Closeout. Tools were categorized by activity and function, encompassing Field Management and Asset Commissioning Platforms such as Autodesk Build and Procore; mobile Defect Management Applications such as Novade and Openspace; Common Data Environments such as Autodesk Construction Cloud and Bentley ProjectWise; COBie validation tools such as Solibri Office; and Handover Management Platforms such as Activeplan and Autodesk Tandem. This taxonomy constituted the empirical foundation for the framework's market assessment stage, ensuring that its evaluation reflects the tools practitioners actually encounter. This objective is comprehensively achieved, providing the industry-facing tool inventory that gives the framework its practical specificity and market relevance.

Answers to Research Questions

Research Question 1 asked what digital tools are currently available in industry and what their core conceptual capabilities regarding structured data management are. This question was answered through comprehensive literature-derived tool taxonomy and practitioner-informed capability assessment. The study established an extensive inventory of tools deployed across handover activities, while simultaneously exposing the implementation gap between tools that nominally support openBIM standards and those that demonstrably produce FM-usable output in practice. This finding underscores a critical industry reality: the presence of capable technology does not guarantee effective data management without intentional alignment between tool functionality and project data requirements.

Research Question 2 asked how organizations currently select digital tools for the handover process. This question was answered through thematic analysis of semi-structured interviews, which revealed a practice landscape characterized by informal, reactive, and activity-agnostic selection decisions that consistently undermine the potential of available technology. Rather than systematic evaluation grounded in handover phase requirements, organizations rely on historical precedent, vendor relationships, or budget availability. This finding identified a clear structural gap in professional practice the absence of a method that translates operational requirements into defensible tool selection decisions which the proposed framework directly addresses.

Research Question 3 asked how a conceptual framework could be structured to evaluate digital tools in alignment with long-term project requirements. This question was answered through the nine-stage Construction-to-FM Handover Tool Evaluation Framework, whose architecture was shaped directly by the convergent findings of the literature review and interview synthesis. Moving sequentially from Handover Phase Identification through Process Definition, Activity Description, Information Need and Responsibility Mapping, Tool Type Identification, Selection Criteria Definition, Market Option Listing, and graded Fitness Assessment, the framework provides the operational logic that existing evaluation models have not delivered. Its illustrative application to the Testing and Commissioning activity demonstrated that this logic is not merely coherent in theory but executable in practice, enabling practitioners to arrive at graded, evidence-based selection decisions that meaningfully distinguish between tools that Fully Fit, Partially Fit, or Poorly Fit the specific requirements of a given handover activity.

Significance and Contribution

Taken together, the findings, analysis, and framework produced by this research constitute a coherent and direct response to the research title: Evaluating Digital Tools for Construction FM Handover. By establishing data quality as the foundational determinant of tool performance, by mapping the current landscape of digital tools against the specific activities they are required to serve, by exposing the structural absence of systematic evaluation practice in the industry, and by proposing a replicable, activity-anchored framework that translates operational requirements into graded market assessments, this study equips construction and FM practitioners with the analytical instrument necessary for informed decision-making. The construction-to-FM handover has long been the phase at which hard-won project intelligence is lost, not because the tools are absent or inadequate, but because the method for choosing and deploying them has never been made explicit. This research makes that method explicit, and in doing so, takes a meaningful step toward ensuring that the information accumulated during construction is preserved, organized, and genuinely useful at the moment it matters most: the point at which an asset moves from those who built it to those who must operate it for decades to come.

6.1 Limitations, Assumptions & Constraints

a. **Methodological Limitations -** The research is grounded in six purposively selected participants, which is defensible for exploratory inquiry but insufficient to support broadly generalizable claims. A single dissenting voice in such a small dataset could materially alter the thematic findings, thereby limiting confidence in conclusions applied beyond the specific professional contexts represented.
b. **Geographic and Contextual Scope -** The comparative analysis between India and the UAE relies predominantly on two participants, with no representation from markets with advanced digital handover maturity such as the UK, Australia, or Scandinavia. This narrow geographic base undermines the breadth of claims made in the broader conclusions.
c. **Rapid Tool Market Evolution** - The digital tool landscape shifts continuously through mergers, discontinuations, and new entrants, making the tool inventory captured in the research time-bound without a defined review mechanism. The market snapshot will require regular updating to maintain practical relevance.
d. **User Capability and Discretion Assumptions** - The framework assumes users possess sufficient digital literacy to navigate its analytical stages and have genuine discretion in tool selection, assumptions that often do not hold in organizations with limited digital maturity or in contexts governed by procurement mandates and client specifications. These constraints are not explicitly addressed within the framework's logic.
e. **Absence of Post-Implementation Feedback** - The framework lacks a mechanism to validate or refine fitness assessments through actual FM outcomes following handover. Without this feedback loop, the framework cannot learn from its application or demonstrate sustained reliability over time.

REFERENCES

Asare, K. A. B., Liu, R., & Anumba, C. J. (2023). Building information modelling for airport facility management: The case of a US airport. *Infrastructure Asset Management*.

Autodesk. (2024). *The complete guide to project commissioning: Digital adoption in AEC*. Autodesk Digital Builder. https://www.autodesk.com/blogs/construction/project-commissioning/

British Standards Institution (BSI). (2013). *PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling*. BSI.

Cavka, H. B., Staub-French, S., & Pottinger, R. (2023). Bridging the gap: A framework for aligning BIM and facility management information requirements. *Advanced Engineering Informatics, 56*, 101952. https://doi.org/10.1016/j.aei.2023.101952

Chatsuwan, Mayurachat, Masayuki Ichinose, and Haitham Alkhalaf. 2025. “Enhancing Facility Management with a BIM and IoT Integration Tool and Framework in an Open Standard Environment.” Buildings 15(11). doi:10.3390/buildings15111928.

Dulguun, Enkhjin. 2023. Implementation of Cutting-Edge Technologies in Facility Management: Challenges and Opportunities in the Digital Era. https://hdpublication.com/index.php/jdmps.

Hashim Lim, S. A., et al. (2024). *Evaluating the effectiveness of mobile-based defect management applications (DMAs) on homebuyer satisfaction in high-rise residential projects*. International Islamic University Malaysia.

Ichendu, Chima, and Gibson Francis Irimiagha. 2024. “Operation and Maintenance Challenges in Building Life Cycle Management: A Literature Review with Insights from Nigeria.” Innovation in Science and Technology 3(4):50–57. doi:10.56397/ist.2024.07.03.

International Organization for Standardization (ISO). (2018). *ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Part 1: Concepts and principles*. ISO.

International Organization for Standardization (ISO). (2018). *ISO 19650-2:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Part 2: Information management and exchange*. ISO.

Khan, Ayaz Ahmad, Abdulkabir Opeyemi Bello, Mohammad Arqam, and Fahim Ullah. 2024. “Integrating Building Information Modelling and Artificial Intelligence in Construction Projects: A Review of Challenges and Mitigation Strategies.” Technologies 12(10).

Kopsida, M., & Brilakis, I. (2024). Digital twin readiness for facility management: A systematic evaluation framework. *Automation in Construction, 158*, 105192. https://doi.org/10.1016/j.autcon.2023.105192

Matthews, J., Love, P. E. D., Porter, S., & Fang, W. (2023). Curating a domain ontology for rework in construction: Challenges and learnings from practice. *Production Planning & Control, 35*(16), 2068–2083. https://doi.org/10.1080/09537287.2023.2223566

Matarneh, Sandra, Faris Elghaish, Farzad Pour Rahimian, Nashwan Dawood, and David Edwards. 2022. “Automated and Interconnected Facility Management System: An Open IFC Cloud-Based BIM Solution.” *Automation in Construction* 143. doi:10.1016/j.autcon.2022.104569

Mayo, Glenda, Tamera McCuen, and Mark Shelbourn. 2023. BIM Data Handover from Construction to Operations. Vol. 4.

Otranto, Rafael Barbosa, Giuseppe Miceli Junior, and Paulo Cesar Pellanda. 2025. “BIM-FM INTEGRATION THROUGH OPENBIM: SOLUTIONS FOR INTEROPERABILITY TOWARDS EFFICIENT OPERATIONS.” Journal of Information Technology in Construction 30:298–318. doi:10.36680/j.itcon.2025.012.

Patacas, M., Dawood, N., & Kassem, M. (2023). BIM for facilities management: A review and a conceptual framework for the selection of information exchange standards. *Journal of Building Engineering, 64*, 105590. https://doi.org/10.1016/j.jobe.2022.105590

Pishdad-Bozorgi, P., Gao, X., & Shelden, D. R. (2022). *BIM-enabled facility management: A guide to computer-aided facilities management (CAFM) and integrated workplace management systems (IWMS)*. Routledge.

Sarkar, D., & Majumder, R. (2023). Challenges in construction-to-facility management handover: A systematic literature review. *Journal of Building Engineering, 68*, 106124. https://doi.org/10.1016/j.jobe.2023.106124

Senthilvel, M., Vasanth, K., & Sivakumar, P. (2022). Integrated common data environment (CDE) for construction projects: A systematic review and future research directions. *Construction Innovation, 22*(5), 980–1005. https://doi.org/10.1108/CI-07-2021-0132

Tsay, Gustavo S., Sheryl Staub-French, Erik Poirier, Puyan Zadeh, and Rachel Pottinger. 2023. "BIM for FM: Understanding Information Quality Issues in Terms of Compliance with Owner's Building Information Modeling Requirements." Frontiers in Built Environment 9. doi:10.3389/fbuil.2023.1117066.

Zanni, M., Soetanto, R., & Ruikar, K. (2022). Defining the BIM handover process: A systematic review of challenges and solutions. *Construction Innovation, 22*(4), 754–776. https://doi.org/10.1108/CI-04-2021-0068

APPENDIX

Appendix 1: Data, Information & Documents by Stakeholder Across Project Phases

Data, Information & Documents by Stakeholder Across Project Phases									
Based on: ISO 19650 (2018); Mayo, McCuen & Shelbourn (2023); Tsay, Staub-French & Poirier (2022); Otranto et al. (2025); Chatsuwan, Ichinose & Alkhalaf (2025); Carvalho et al. (2023)									
Stakeholder	**Primary Role**	**Project Initiation**	**Planning & Schematic Design**	**Detailed Design & BIM Authoring**	**Procurement & Tendering**	**Construction**	**Testing & Commissioning**	**Handover / Close-Out**	**Operations & Maintenance (O&M)**
Owner / Client	*Project Funder & Decision Maker*	Project Brief Business Case Feasibility Study Strategic Objectives Budget Approval Site Selection Report	Employer's Information Requirements (EIR) Organisational Information Requirements (OIR) Asset Information Requirements (AIR) Sustainability Targets Funding Approvals	Design Review Approvals Stage Gate Sign-offs Value Engineering Decisions BIM Model Reviews	Contract Agreements Tender Approvals Procurement Strategy Letter of Award	Change Order (CO) Approvals Progress Payment Certification Variation Approvals Client Change Requests	Final Acceptance Certificate Defects Liability Approval Occupancy Approval Performance KPI Baseline Setting	Formal Handover Acceptance Defects Liability Certificate Final Account Approval AIM Ownership Transfer	Asset Performance KPIs Lifecycle Cost Benchmarks Capital Replacement Plan Insurance & Compliance Records
Project Manager (PM / PMC)	*Programme & Risk Management*	Stakeholder Register Risk Register Project Initiation Document (PID) Project Charter	WBS Gantt Chart Cost Baseline Quality Plan Communication Plan BIM Strategy Note	Design Coordination Reports Issue Log RFI Log Management Change Register	Tender Evaluation Report Procurement Schedule Contract Admin Documents	RFI Log Issue Log DPR (Daily Progress Report) Meeting Minutes Earned Value Reports Site Instructions (SI)	Closure Report Lessons Learned Register Commissioning Oversight Records	Handover Checklist Practical Completion Notice Defects Punch List Final Report Project Closeout Register	Performance Monitoring Reports post-occupancy Evaluation (POE) Lessons Learned Feedback to Future Projects
Architect	*Design Lead &*	Conceptual Design	Schematic Drawings	Detailed Drawings	Tender Drawings Bill of Quantities	RFI Responses Site Instructions	As-Built Architectural	As-Built Architectural	Space Utilisation Data (if post-

Data, Information & Documents by Stakeholder Across Project Phases									
Based on: ISO 19650 (2018); Mayo, McCuen & Shelbourn (2023); Tsay, Staub-French & Poirier (2022); Otranto et al. (2025); Chatsuwan, Ichinose & Alkhalaf (2025); Carvalho et al. (2023)									
Stakeholder	**Primary Role**	**Project Initiation**	**Planning & Schematic Design**	**Detailed Design & BIM Authoring**	**Procurement & Tendering**	**Construction**	**Testing & Commissioning**	**Handover / Close-Out**	**Operations & Maintenance (O&M)**
	BIM Authoring	Sketch Drawings Site Analysis Report Design Brief Response	Design Basis Report IFC (Issued for Comment) Drawings Room Data Sheets Space Programme	IFC (Issued for Construction) BIM Model (LOD 300) Specifications Design Development Report	Input Tender Spec Documents	(SI) Design Clarifications Shop Drawing Reviews	Drawings Snagging Support	Drawings (Final) Space Utilisation Handover Report	occupancy review involved) Design Defect Analysis
Structural Engineer	*Structural Design & Analysis*	Preliminary Structural Concept Geotechnical Assessment Note	Structural Analysis Report Calculation Sheets Reinforcement Drawings (Prelim)	Final Structural Calculations Reinforcement Drawings BIM Model – Structural (LOD 300) Foundation Design	Technical Specifications Bill of Quantities Input	Bar Bending Schedule (BBS) Structural Inspection Reports RFI Responses NC Records	As-Built Structural Drawings Structural Integrity Inspection Report	As-Built Structural Drawings (Final) Structural Completion Certificate	Structural Integrity Assessment Data (if required for renovation / audit)
MEP Engineer (Mechanical, Electrical & Plumbing)	*Building Systems Design & BIM*	MEP Concept Note System Selection Report Load Estimates	MEP Layout Drawings Equipment Schedules Load Calculations EnergyModel Reports	MEP BIM Model (LOD 300–350) Coordinated MEP Drawings Federated Model Input Spec Sheets	Technical Submittal Review Equipment Procurement Input BOM (Bill of Materials)	Shop Drawing Reviews Testing & Commissioning (T&C) Plan Inspection Reports RFI Responses	T&C Reports Equipment Test Certificates O&M Manuals (draft) PM Schedules (initial draft) COBie Asset Data (Type / Component)	O&M Manuals (final) Equipment Test Certificates (final) COBie Data (complete) As-Built MEP Drawings Warranty Log	Preventive Maintenance Schedule (activated) Asset Register (COBie / AIM) Warranty Tracking Documentation Energy Performance Reports
Quantity Surveyor (QS / Cost Manager)	*Cost Planning & Quantification*	Preliminary Cost Estimate Order of Magnitude Budget	BOQ (Bill of Quantities) Cost Plan Rate Analysis Value Engineering Report	Detailed Cost Plan Life Cycle Cost Analysis (LCCA) Specification Input	Tender Documents Bid Analysis Report Contract Sum Analysis	Interim Payment Certificate (IPC) Variation Order (VO) Cost Reports Cash Flow Forecasts	Penultimate Account Statement Snagging Cost Assessment	Final Account Statement Defects Rectification Cost Records Lifecycle Cost Report	Lifecycle Cost Reports Capital Expenditure Forecasts Asset Replacement Schedule

Data, Information & Documents by Stakeholder Across Project Phases									
Based on: ISO 19650 (2018); Mayo, McCuen & Shelbourn (2023); Tsay, Staub-French & Poirier (2022); Otranto et al. (2025); Chatsuwan, Ichinose & Alkhalaf (2025); Carvalho et al. (2023)									
Stakeholder	**Primary Role**	**Project Initiation**	**Planning & Schematic Design**	**Detailed Design & BIM Authoring**	**Procurement & Tendering**	**Construction**	**Testing & Commissioning**	**Handover / Close-Out**	**Operations & Maintenance (O&M)**
					Procurement Schedule				
Main Contractor	*Site Construction & QA/QC*	Constructability Input Site Logistics Plan (prelim)	Construction Method Statement Master Programme (Gantt) Site Establishment Plan	Subcontract Package Plans Material Procurement Schedule Construction BIM Input (LOD 300+)	Bid Submission Subcontract Agreements Procurement Schedule	RFI Log QA/QC Checklists ITP (Inspection & Test Plan) Site Diary NCR (Non-Conformance Report) Safety Plan Material Submittals	Snagging Records Punch List Completion Certificate As-Built Drawings (all disciplines)	As-Built Drawings (Final) Defects Rectification Records COBie Handover Package Warranty Package Occupancy Certificate Support	Defects Rectification Records (DLP) Warranty Support Documentation
Subcontractor (MEP / Specialist)	*Specialist Works & Installation*	Technical Capability Statement	Shop Drawing Submittals (Prelim) Material Proposals	Shop Drawings Technical Data Sheets Method Statements	Material Procurement Records Delivery Schedule	Work Method Statements Installation Reports QA/QC Records Shop Drawing Revisions	Commissioning Assistance Records Test Results Warranty Certificates (Equipment Level)	Warranty Certificates (final) As-Installed Drawings Maintenance Support Documentation	Maintenance Support Documentation Warranty Claim Support
Suppliers / Vendors	*Material & Equipment Supply*	Product Prequalification Data	Technical Data Sheets Product Catalogues Performance Specs	Equipment Schedules BIM Object Data (LOD 200+) Manufacturer Specs	Delivery Schedule Factory Test Certificate (FTC) Tax Invoice	Delivery Challan Factory Test Certificates Installation Guidance Notes	Equipment Test Certificates Warranty & Guarantee Certificates Spare Parts List (initial)	Warranty & Guarantee Certificates (final) Spare Parts List (final) O&M Manuals (Equipment-Level)	Spare Parts Supply Records Warranty Claim Resolution Replacement Parts Data
BIM Manager / Digital Lead	*BIM & CDE Governance*	BIM Strategy Note Digital Delivery Plan (prelim)	BIM Execution Plan (BEP) Model	Federated BIM Model Clash Detection Report	Data Exchange Protocol BIM Compliance Checklist	Federated Model Updates Clash Detection Reports	As-Built BIM Model (LOD 500) COBie	Final As-Built BIM (LOD 500) Validated COBie Spreadsheet	FM-Integrated Digital Model (linked to CMMS) AIM Updates

Data, Information & Documents by Stakeholder Across Project Phases									
Based on: ISO 19650 (2018); Mayo, McCuen & Shelbourn (2023); Tsay, Staub-French & Poirier (2022); Otranto et al. (2025); Chatsuwan, Ichinose & Alkhalaf (2025); Carvalho et al. (2023)									
Stakeholder	**Primary Role**	**Project Initiation**	**Planning & Schematic Design**	**Detailed Design & BIM Authoring**	**Procurement & Tendering**	**Construction**	**Testing & Commissioning**	**Handover / Close-Out**	**Operations & Maintenance (O&M)**
			Coordination Report CDE Setup Common Data Environment (CDE) Protocol	BIM Model (LOD 300–350) Data Exchange Protocol (DEP) Master Information Delivery Plan (MIDP)		COBie Data Sheets (draft) RFI Coordination Log	Validation Report Asset Information Model (AIM) draft Data Drop 3 Package	AIM (Asset Information Model) CDE Handover Transfer IFC Export (final)	Digital Twin Readiness Report
Commissioning Agent / CxA	*T&C Planning & Verification*	Commissioning Plan (prelim)	Cx Plan Development System Cx Requirements	Design Review Comments (Cx perspective) Cx Specification Input	Cx Contractor Evaluation Input	Pre-functional Checklists Functional Performance Test (FPT) Plans Issue Log (Cx)	Functional Performance Test Results Commissioning Report System Set-point Data Acceptance Criteria Records CxAlloy / Platform Data	Final Cx Report COBie Job Data (maintenance tasks) As-Commissioned Asset Records	Seasonal Cx (if applicable) Retrocommissioning Support
Regulatory Authorities	*Statutory Approvals*	Land Use Approval Environmental Clearance Zoning Approval	Building Permit Fire NOC (preliminary) Environmental Clearance	Drawing Approval Specification Approval	Permit to Commence Work	Inspection Reports Fire NOC (interim) Site Compliance Checks	Occupancy Certificate (OC) Completion Certificate Fire NOC (final) Lift Inspection Certificate	Final Occupancy Certificate Fire Safety Compliance Cert Building Completion Certificate	Compliance Audit Records Periodic Inspection Certificates Fire Drill Records
Health & Safety Officer (HSE)	*Site Safety & Compliance*	Risk Identification Notes HSE Policy Statement	HSE Plan Construction Phase Plan Emergency Response Plan	Hazard Identification Report Method Statement Review	Contractor Safety Evaluation Input	Toolbox Talk Records Incident Reports Safety Audit Reports ITP Safety	Safety Compliance Certification Final Safety Audit Report	Health & Safety File (Golden File) Safety Compliance Certificate	Safety Performance Logs Incident & Near-Miss Records Fire Evacuation Drill Records

Data, Information & Documents by Stakeholder Across Project Phases									
Based on: ISO 19650 (2018); Mayo, McCuen & Shelbourn (2023); Tsay, Staub-French & Poirier (2022); Otranto et al. (2025); Chatsuwan, Ichinose & Alkhalaf (2025); Carvalho et al. (2023)									
Stakeholder	**Primary Role**	**Project Initiation**	**Planning & Schematic Design**	**Detailed Design & BIM Authoring**	**Procurement & Tendering**	**Construction**	**Testing & Commissioning**	**Handover / Close-Out**	**Operations & Maintenance (O&M)**
						Checks Safety Statistics		Fire Safety Handover Report	
Facility Manager (FM)	*FM Operations & Asset Mgmt*	Operational Requirements Input FM Brief Statements	Maintainability Review Comments Operational Data Requirements (feeds AIR) Soft Landings Engagement	FM Design Review Comments Room Data Sheet Review Equipment Maintainability Input	FM System Procurement Input (CMMS selection)	Site Observation Notes FM Readiness Checklist (in-progress)	Asset Register (draft) CMMS Setup Preparation FM Team Training Plan	Asset Register (AIM – activated) O&M Manuals (received & filed) Warranty Log PM Schedules (activated in CMMS) Soft Landings Aftercare Plan	CMMS Records Work Orders Maintenance Logs Energy Consumption Reports Warranty Tracking KPI Reports Asset Lifecycle Planning Post-Occupancy Evaluation (POE)
IT / Digital Lead (FM Side)	*FM IT Systems & Digital Tools*	IT Infrastructure Plan (prelim)	CMMS / IWMS Selection Criteria Digital Tool Evaluation Matrix	BIM-to-CMMS Mapping Plan Data Schema Alignment Review	FM Software Procurement Contracts	CMMS Configuration (in-progress) ACC / CDE Access Setup	CMMS Test Environment Setup COBie Import Test Run	COBie → CMMS Full Import AIM Integration Records User Access Configuration API Integration Log (BMS ↔ CMMS)	CMMS Administration Logs Data Backup Records System Upgrade Reports AI Tool Integration Records (if applicable)

Appendix 2: Critical FM data - Deliverables

	Deliverable	Responsible Stakeholder
1	As-Built BIM Model (LOD 500) Field-verified, all disciplines	BIM Manager / Digital Lead
2	Validated COBie Spreadsheet (Asset data for all maintainable equipment)	BIM Manager / Digital Lead
3	Full O&M Manuals (Linked to assets in COBie / model)	Main Contractor (coordinates all submissions)
4	Commissioning Records & T&C Reports (Test & Commissioning: all building systems)	Main Contractor (collates all)/Commissioning Agent
5	Warranty & Guarantee Certificates (All installed equipment)	Main Contractor (collates all)
6	As-Built Drawings (All disciplines, all formats)	Lead Designer / Architect (coordinates all consultants)
7	Spare Parts Lists (Recommended spares per equipment type)	Equipment Vendors / Suppliers
8	Preventive Maintenance Schedules (PPM: per asset, activated in CMMS)	MEP Engineer / Commissioning Agent
9	Occupancy Certificate (OC) & Regulatory Sign-Offs	Main Contractor (applies; coordinates with authorities)
10	Fire Safety & Life Safety Certificates (Fire NOC, sprinkler test, alarm certificates)	Main Contractor & HSE Officer (coordinate applications)
11	Final Account Records (Complete financial closure of the contract)	Quantity Surveyor (QS / Cost Manager)
12	AIM: Asset Information Model (Complete operational dataset for FM)	BIM Manager / Digital Lead (compiles from all above)

Appendix 3: Divergent findings

Concept / Theory	Literature Prescribes (Post-2021)	Ground Reality (Practitioner Interviews)	Participant & Source	Theoretical Implication of Divergence
Structured Data Delivery via COBie	Post-2021 literature mandates formal COBie delivery at handover milestone (Data Drop 3) as a contractually structured, machine-readable asset information exchange. Zanni et al. (2022) and Patacas et al. (2023) position COBie compliance as a baseline expectation for FM-ready handover.	Small-to-medium projects in India transmit handover documentation via WhatsApp and email in PDF, DWG, and SKP formats. Physical hard copies are submitted in parallel. COBie is not generated, referenced, or known to many project stakeholders.	P1, P2 Zanni et al. (2022); Patacas et al. (2023)	*Literature's prescriptive models presuppose a market maturity that does not exist across geographies. The conflict reveals that COBie is a ceiling standard being promoted as a floor requirement, resulting in a compliance gap that no framework currently addresses for transitional markets.*
BIM as a Lifecycle Data Management Tool (6D/7D)	ISO 19650, Chatsuwan et al. (2025), and Otranto et al. (2025) frame BIM as a lifecycle instrument extending into FM (6D sustainability, 7D asset management). Digital Twin integration with FM platforms is presented as an emerging standard.	In India, BIM adoption is predominantly confined to 3D visualisation and, at best, 5D cost estimation on larger infrastructure projects. 6D and 7D BIM remain aspirational. Digital Twin deployment is absent in the domestic market contexts described.	P1, P2 Chatsuwan et al. (2025); Kopsida & Brilakis (2024)	*The literature's evolutionary BIM narrative (3D → 7D) is geographically bounded. In transitional markets, adoption has stalled at a stage the literature treats as an intermediate step, not a terminus. Frameworks that assume forward-moving BIM maturity are inapplicable to a large portion of the global industry.*

Concept / Theory	Literature Prescribes (Post-2021)	Ground Reality (Practitioner Interviews)	Participant & Source	Theoretical Implication of Divergence
CDE as the Centralised Single Source of Truth	Senthilvel et al. (2022) and ISO 19650 position the CDE as the non-negotiable governance mechanism for all project information. CDEs enforce document status workflows (WIP → Shared → Published → Archived) and eliminate fragmentation.	Government projects in India use a statutory online portal as a de facto CDE for uploading approvals and compliance documents. The platform is not chosen for FM alignment; it is mandated by regulation. No ISO 19650-compliant status workflow is applied. In small projects, the "CDE" is effectively a shared Gmail or WhatsApp group.	P5; P1, P2 Senthilvel et al. (2022); Sarkar & Majumder (2023)	*The literature treats CDE adoption as a question of organisational digital maturity, but the interview data reveals that CDE deployment is frequently driven by regulatory mandate rather than information management intent. A government portal that functions as a statutory repository is structurally different from a CDE, yet is indistinguishable from it in terms of actual usage, exposing a definitional conflation in current frameworks.*
Systematic, Criteria-Based Tool Selection	Frameworks by Pishdad-Bozorgi et al. (2022), Sarkar & Majumder (2023), and Zanni et al. (2022) advocate for multi-criteria, data-readiness-led tool selection processes grounded in	Tool selection in practice is driven by familiarity, project cost constraints, client preference, and vendor influence. Document naming conventions are often undefined until mid-	P3, P4 Pishdad-Bozorgi et al. (2022); Sarkar & Majumder (2023)	*The gap between prescriptive selection frameworks and actual practice is not merely a knowledge gap; it reflects a structural disincentive. Contractors bear the cost of tool implementation but the FM*

Concept / Theory	Literature Prescribes (Post-2021)	Ground Reality (Practitioner Interviews)	Participant & Source	Theoretical Implication of Divergence
	EIR/AIR alignment and organisational digital maturity.	project, and are either imposed by the client retroactively or improvised by the BIM team. No evidence of formal evaluation criteria usage was reported.		*benefits accrue to the owner. Until contractual mechanisms align these interests, evidence-based tool selection will remain aspirational rather than operational.*
Early FM Stakeholder Involvement	BSRIA BG 54/2018 and associated literature require FM team involvement from the inception stage. Tsay et al. (2022) demonstrate that information requirements must be defined early and assigned formally to avoid handover failure.	FM software vendor involvement (P6) is dictated entirely by client request, occurring either at project initiation or post-construction completion. There is no evidence of a formal FM involvement process or early FM engagement mandate in the projects described. Third-party handover consultants are appointed reactively, not strategically.	P3, P6 Tsay et al. (2022); Ichendu & Irimiagha (2024)	*The Soft Landings model assumes a procurement environment where the client actively manages the post-occupancy transition from the briefing stage. The interview data suggests that the typical client-contractor relationship does not create the conditions for this. The FM vendor's involvement is a late commercial decision, not an embedded project governance obligation.*
openBIM Interoperability (IFC/COBie) as Functional Reality	Otranto et al. (2025), Chatsuwan et al. (2025), and Matarneh et al. (2022) present the openBIM ecosystem (IFC,	PMIS naming conventions are either absent or improvised. IFC exports are inconsistently generated. The only structured	P4 Otranto et al. (2025); Sarkar & Majumder (2023)	*The openBIM literature presents interoperability as a solved architectural problem awaiting implementation. The interview*

Concept / Theory	Literature Prescribes (Post-2021)	Ground Reality (Practitioner Interviews)	Participant & Source	Theoretical Implication of Divergence
	COBie, IDS, BCF) as an increasingly operational standard enabling lossless data transfer across authoring and FM platforms.	data exchange described in the interviews involves Aconex for document transmission, which uses no openBIM standards. Handover packages are submitted in proprietary or semi-structured formats.		*data suggests the implementation barrier is not technical but organisational: naming conventions, data schemas, and exchange specifications are not established at project outset. Interoperability fails not because tools cannot exchange IFC, but because no one has defined what a valid IFC export looks like for that specific project.*
Handover Modality: Digital-First Workflow	Pishdad-Bozorgi et al. (2022), Chatsuwan et al. (2025), and Sarkar & Majumder (2023) describe digital handover as the standard mode of operation, with BIM-to-FM data transfer via structured platforms framing paper-based processes as a legacy exception.	Three distinct handover modalities co-exist simultaneously: traditional (printed plans, manual marking), hybrid (barcode/QR scanning linked to digital records), and delegated (third-party consultant manages the digital workflow). The traditional modality remains active on current projects, not as an exception but as a recognised	P3 Zanni et al. (2022); Ichendu & Irimiagha (2024)	*The literature's binary framing of traditional versus digital handover is empirically inaccurate. The three-modality landscape revealed in the interviews suggests a more granular taxonomy is needed, one that acknowledges hybrid and delegated modes as legitimate, stable configurations rather than transitional states on a path to full digitalisation.*

Concept / Theory	Literature Prescribes (Post-2021)	Ground Reality (Practitioner Interviews)	Participant & Source	Theoretical Implication of Divergence
		operational mode.		
Digital Twins as FM Operational Tools	Kopsida & Brilakis (2024) position Digital Twin readiness as an evaluable criterion for handover tools, implying that live AIM synchronisation is a near-term operational expectation. Autodesk (2024) and Chatsuwan et al. (2025) reference AR/VR-enabled twin overlays as emerging commissioning tools.	No participant described using a Digital Twin in an operational FM context. Digital Twin is referenced by P2 in the context of UAE adoption, framed as an advanced aspiration rather than a current deployment. IoT sensor integration and AR overlay for commissioning were not reported in any of the six interviews.	P1, P2 Kopsida & Brilakis (2024); Chatsuwan et al. (2025)	*Digital Twin literature is normalising a technology that is operational only in the most advanced market segments. Its inclusion as a standard evaluation criterion in frameworks risks creating a capability standard that the majority of real-world projects cannot meet, thereby rendering the framework inapplicable to the bulk of the industry.*

Appendix 4: Semi structured interview questions and comparison of answers

Given below are the five key questions asked to the participants in semi-structured interview conducted.

1. **Primary criterion?**
   "When selecting digital tools for handover activities, what is your team's top single criterion (cost, interoperability/IFC support, ease of use/training time, vendor reputation, scalability, data validation features, mobile access)?"
2. **COBie usage?**
   "How frequently does your team use COBie spreadsheets during handover? (Never / Rarely / Sometimes / Frequently / Mandatory for all projects)"
3. **Biggest barrier?**
   "What is the single biggest barrier preventing effective digital tool adoption in handover? (Skills gap/training, data quality issues, vendor lock-in/contracts, cost/budget, management buy-in, interoperability failures, lack of standards)"
4. **BIM maturity level?**
   "What BIM level does your organization typically reach at handover? (2D CAD / 3D modeling / 4D scheduling / 5D costing / 6D sustainability / 7D FM-ready)"
5. **Handover modality?**
   "Which handover workflow describes your typical process or you think is followed as per your knowledge? (Manual: paper-based / Hybrid: Excel+apps / Platform-driven: fully digital)"

Side-by-side participants views on key questions asked:

Comparative Participants Response Table

Question	**P1 (FM assistant faculty)**	**P2 (BIM Manager)**	**P3 (VDC manager)**	**P4 (Document controller)**	**P5 (Project Manager)**	**P6 (FM software vendor)**
Primary criterion?	Cost	Interoperability	Ease of use	Data validation	Scalability	Standards (IFC)
COBie usage?	Never	Mandatory	Sometimes	Frequently	Rarely	Mandatory
Biggest barrier?	Skills gap	Data quality	Vendor lock-in	Late FM input	Budget cuts	Fragmented tools
BIM maturity reached?	3D modelling (In India)	4D scheduling (In India) 7D FM-ready (In other regions like UAE)	4D scheduling, 5D costing (In India)	5D costing (In other regions like UAE)	3D modelling (In India)	7D FM-ready (In other regions like UAE)
Handover method?	Manual; Hybrid as per project	Hybrid; Platform-driven (as per client)	Hybrid; Platform-driven (as per client)	Platform-driven (as per client)	Manual; Hybrid (as per client)	Platform-driven (as per client)

- P1-P3: India (emerging BIM markets, still at 5D); P2, P4: other regions like UAE (more mature).
- Reveals clear geographic patterns: India prioritizes cost/ease over standards; other regions like UAE emphasizes data quality/interoperability