DIRECTED RESEARCH PROJECT

Evaluating Digital Tools for Construction – FM Handover

Kalyani Vijaykumar Dehankar

PCM24485

Master of Technology – Construction Engineering & Management

Faculty of Technology, CEPT University

Guide: Siddharth Panjwani | Co-guide: Dr Amarnath CB

The Handover Challenge

The transition from construction to facility management represents one of the most complex and inefficient stages in digital information management. Despite BIM adoption, stakeholders face fragmented workflows, lack of standardization, and poor coordination.

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**.

Objectives

1. **Current Tool Selection Practices**
2. **Data Quality Impact**
3. **Tool Categorization**
4. **Evaluation Framework**

Research Questions

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

RQ2: How does the quality and completeness of structured handover data affect the performance of digital tools used during the construction-to-FM handover?

RQ3: How organizations currently select digital tools for the handover process?

RQ4: How can a conceptual framework be structured to effectively evaluate these digital tools to ensure they align with the project's long-term requirements?

Research Methodology

Multi-Method Qualitative Design Approach: Exploratory approach focusing on understanding the "how" and "why" behind digital tool selection decisions. Captures experiential insights from industry stakeholders.

Two-Phase Approach

LR

Literature Review

Comprehensive review of academic literature to identify existing digital handover frameworks and global trends. Provides thematic foundation for primary data collection.

SI

Semi-Structured Interviews

Gather "on-the-ground" empirical data to validate or challenge literature findings by comparing against industry reality.

Participant Profiles: FM professionals and educators, Project Managers, BIM or Digital Coordination professionals, O&M Consultants
Sample Size: 8-10 semi-structured interviews

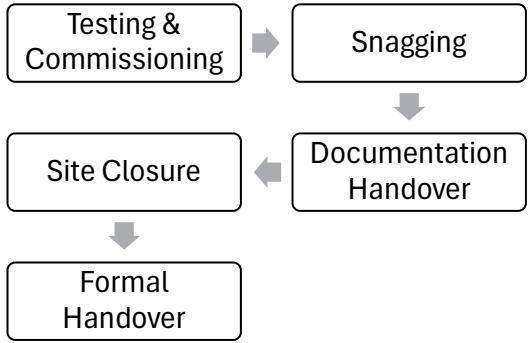
Ethical Considerations

Strict anonymity granted to all participants. Identifiable information redacted; participants referred using alphanumeric identifiers (P1, P2, etc.).

Project Lifecycle

1. Feasibility Phase
2. Design Phase
3. Construction Phase
4. **Handover Phase**
5. Facility Management Phase

Key Activities included :



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 work
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 meeting, approval and acceptance • Transfer of ownership and occupancy • Project completion certification

Transition of Process

Traditional Handover Process - Challenges

Paper-Based Documentation

Fragmented Information

Information Loss

Manual Data Re-entry

Result: Inefficient, error-prone, incomplete data

Digital Handover Process

BIM & CDE Integration

Structured Data Schemas

Digital Twin Representation

Machine-Readable Formats

Result: Efficient, accurate, actionable data

References: (Mayo, McCuen, and Shelbourn 2023; Singh & Anumba, 2023; Tavakolan et al., 2022; Asare et al., 2023; Pishdad-Bozorgi et al., 2022; Sarkar & Majumder, 2023; Zanni et al., 2022)

Digital Handover Process – openBIM Approach

openBIM is a collaborative process based on vendor-neutral standards and file formats developed primarily by buildingSMART International. It enables seamless data exchange and interoperability between different stakeholders and software systems across the project lifecycle.

1. Data Standards (File Formats) - These are the core formats used to exchange actual model information and handover data.

i. **IFC -** *Common extensions:* .ifc, .ifczip, .ifcxml.
ii. **COBie -** delivered as a spreadsheet (.xlsx or .csv)

2. Communication & Workflow Standards - These standards manage how teams talk to each other and how data is filtered for specific uses.

i. **BCF (BIM Collaboration Format):** An open format used for issue tracking. Common extensions: .bcf, .bcfzip.
ii. **IDS (Information Delivery Specification):**
iii. **MVD (Model View Definition):** A subset of the IFC schema. MVD filters the data for a specific use case (e.g., "Coordination View" or "Structural Analysis View").
iv. **IDM (Information Delivery Manual):** The Information Delivery Manual (IDM) is mentioned in the ISO 19650 series primarily as a method for defining information requirements and exchange processes

3. Service & Dictionary Standards

i. **bSDD (buildingSMART Data Dictionary):** A cloud-based service that maps different technical terms and classifications to a standard set of definitions.
ii. **openCDE APIs:** A set of APIs designed to allow different CDEs to communicate seamlessly

openBIM Environment – Digital tools categories

The tools maturity and complexity increases as it moves from standalone tools to asset management

	Category 1 Standalone Tools (Fragmented)	Category 2 Collaboration Suites (Centralized)	Category 3 Asset Management Platforms (Operational Lifecycle)
What they are	Dedicated software designed for a specific function, operating independently without connecting to a central database.	A suite of applications that share a centralized database, allowing instant data flow between modules.	A system focused on tracking assets throughout their lifetime from commissioning to disposal.
Ex	MS Word, MS Excel	ACC	IBM Maximo
	Low maturity, less complexity	Moderate maturity, Moderate complexity	High maturity, High complexity

References: (Mayo, McCuen, and Shelbourn 2023; Singh & Anumba, 2023; Tavakolan et al., 2022; Asare et al., 2023; Pishdad-Bozorgi et al., 2022; Sarkar & Majumder, 2023; Zanni et al., 2022)

Existing tool evaluation framework

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.

- Most frameworks strongly emphasize **data structure, interoperability, and standardization**, highlighting the importance of seamless information exchange (e.g., BIM, IFC, COBie integration).
- However, there is comparatively **limited attention to user-centric factors**, such as ease of adoption, stakeholder collaboration, and training requirements.
- Also, they don't address small/medium private projects

Digital tools used in Handover Process

Testing & Commissioning
Field Management & Asset Platforms - Autodesk Build, Procore and CxAlloy

Snagging
Mobile Defect Management Applications (DMAs): Novade
Photo & Video Documentation: Openspace
Automated Workflows & Notifications: Procore (Punch List Tool)
Aggregated Analytics: Autodesk (Build)

Documentation
CDE with Version Control - ACC
Automated COBie and Metadata Validation Tools – Solibri Office
AIR Management Platforms – Gliderbim

Handover
Handover Management & Digital Manual Platforms – Activeplan
Digital Twin & AIM Platforms - Autodesk Tandem
Data Integration & Middleware Tools – EcoDomus

Research findings provide a direct answer to RQ1
The findings indicate that the selection process is driven by the tool's ability to integrate with BIM and CDE, ensuring that the digital connect remains unbroken during the transition from construction to operations.

References: (Pishdad-Bozorgi et al., 2022; Sarkar & Majumder, 2023; Hashim et al., 2024; Senthilvel et al. 2022; Patacas et al. , 2023; Cavka et al., 2023; Zanni et al. ,2022; Kopsida & Brilakis ,2024)

Challenges in Digital Handover Process

Process

Late Delivery of Information
Data compiled only at project end, leaving insufficient time for validation

Lack of Structured Workflows
Unclear information requirements create ambiguity across stakeholders

Limited FM Involvement
Disconnect between delivered information and operational needs

Fragmented Workflows
Unclear acceptance criteria causing validation inefficiencies

Results in

Technology

Interoperability Limitations
Inconsistent schema implementation, semantic discrepancies

Data Fragmentation
Multiple tools operating in isolation create data silos

Poor Data Quality
Non-machine-readable formats, incomplete information

Tool Complexity
Varying software capabilities create integration barriers

Results in

Human/Organization

Lack of Skills & Expertise
Teams lack BIM and digital system competencies

Resistance to Digital Adoption
Organizational inertia, reluctance to change practices

Lack of Trust in Digital Data
Concerns over data reliability limit acceptance

Incentive Misalignment
Benefits realized in later stages reduce motivation

Research findings provide a direct answer to RQ2 by establishing that the operational performance of digital tools is intrinsically linked to the integrity of the data provided. It is evident that even the most advanced digital platforms cannot function effectively if the data provided during the handover phase is incomplete or poorly structured. ***The findings indicate that digital tools are essentially "data-dependent" systems; their ability to facilitate asset tracking or maintenance planning is entirely dictated by the quality and completeness of the structured data ingested.***

References: (Mayo, McCuen, and Shelbourn 2023; Singh & Anumba, 2023; Tavakolan et al., 2022; Asare et al., 2023; Pishdad-Bozorgi et al., 2022; Sarkar & Majumder, 2023; Zanni et al., 2022)

PHASE 2 – SEMI STRUCTURED INTERVIEWS

Participant Profiles (n=6)

P1 **Facility Management Assistant**
Private University

P2 **BIM Manager**
BIM Consulting Firm

P3 **VDC Manager**
Tier-1 Construction MNC

P4 **Document Controller**
Tier-1 Construction MNC

P5 **Project Manager**
Real Estate Company

P6 **FM Software Vendor**
Specialized Software Company

Key Findings from Interviews

Large-Scale Projects (Out of India)

- Prioritize centralized information management
- Utilize high-end CDEs: **ACC, Oracle Aconex as per clients needs**
- FM digital tools are necessity for managing thousands of documents
- Automated workflows for large teams

Small-to-Medium Scale Projects (In India)

- Digital adoption is "fragmented“
- Revert to manual methods: **WhatsApp, Gmail, PDFs**
- Cost of specialized software outweighs perceived benefits
- Resistance to invest in tools

Government Projects (In India)

- Government avoid popular tools like Aconex or ACC to mitigate third-party risk for data safety
- Online government portals ensure domestic jurisdiction

Large scale Real Estate Developers (In India)

- They have their own end to end ERP (Enterprise resource planning) software solution

Industrial Projects (In India)

- Using **mail** for collaboration and raised quality observation
- **MSP and Primavera** for scheduling and planning
- **GDrive** for storage so that all stakeholders can access
- Lack of Knowledge and proficiency of softwares

Tool Selection Factors identified based on interviews

Nature Of The Project

Complexity Of The Project

Technological Needs

Budget of the project

RESEARCH GAP

While existing literature extensively documents the ideal technical requirements for digital handover such as the necessity for openBIM standards (IFC, COBie), CDE and AIR; a significant gap exists in how these frameworks translate to the ***small-to-medium projects*** *(****private residential and commercial sectors****)*

According to interviews, construction and FM organizations select digital tools for the handover process primarily based on clients needs followed by project scale, cost and regulatory requirements. Large and complex projects adopt advanced CDE platforms like ACC or Oracle Aconex to manage high data volumes and workflows, whereas ***small-to-medium projects*** *rely on low-cost or manual methods due to budget constraints and limited perceived benefits, which* ***significantly influence tool selection, often overriding technological preferences.***

The gap is identified as:

The "Human-Process" Implementation Gap

This research bridges this gap by proposing a ***Practical Evaluation Framework*** *that aligns* ***complexity and technological needs of the project*** *with the appropriate level of* ***digital tool maturity (category)****.*

The framework will be useful for the clients focusing on small to medium scaled projects

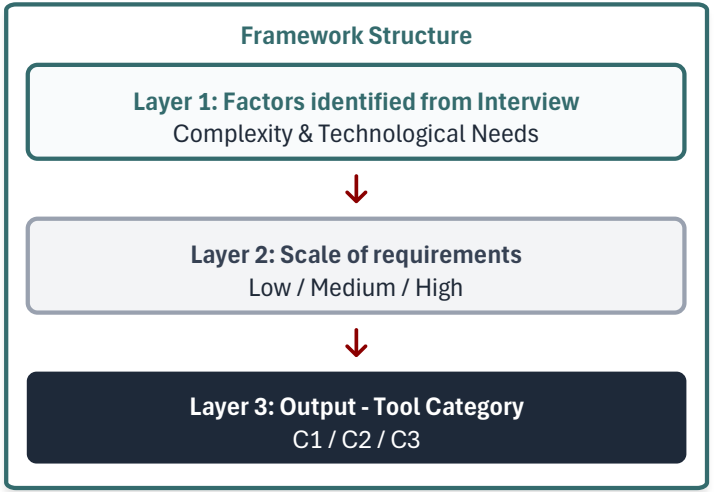
Literature study gave categories of digital tools with:
C1 – Less complexity (standalone tools)
C2 – medium complexity (collaboration suites)
C3 – high complexity (asset management platforms)

Interviews gave the two selection factors
1. **Complexity of Project** (physical/organizational intricacy: MEP density, number of stakeholders, project scale)
2. **Technical Needs of Project** (functional requirements: real-time monitoring, BIM-FM integration, digital twin need)

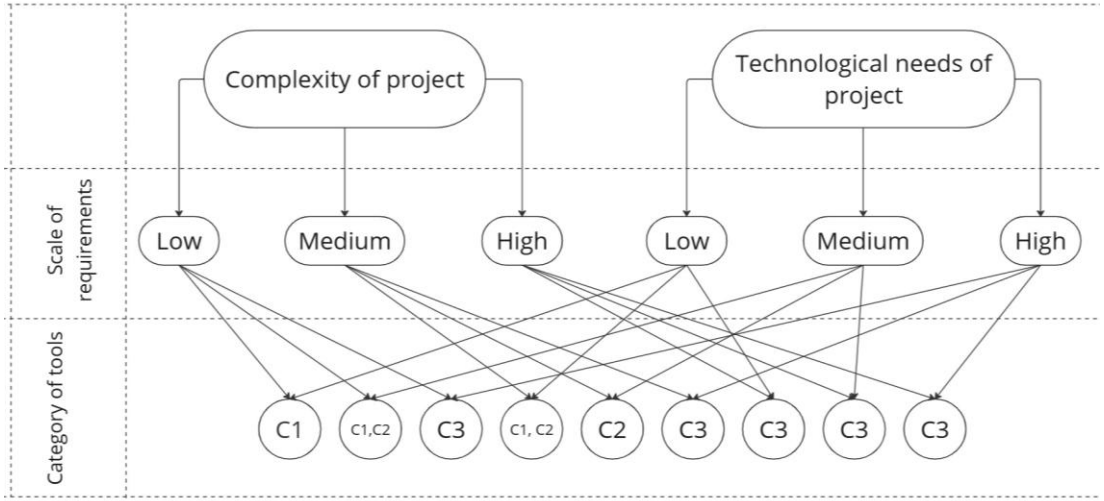
Selected softwares are considered for the framework – Gmail, Google drive, MS office, ERP solution, ACC, Aconex, CxAlloy and openBIM formats (examples from literature study and interviews)

These two streams together form the basis for a framework

Theoretical framework
Layer 1 – Factors identified from Interviews
Complexity of Project and Technical Needs of Project
Layer 2 – Scale of requirements
low, medium , high (based on nature of project, the two factors identified from interviews will be measured into three separate parts by the client)
Here, if client wants to focus on one factor only (either complexity or technical needs) then at layer 2 only the client finds the answers. If it is low – less complexity tools, medium – moderate complexity tools, high – high complexity tools. If the client decides to consider both factors in layer 1 then, layer 3 will be needed
Layer 3 – Category of tools
It will consist of C1 – Less complexity tools, C2 – medium complexity tools , C3 – high complexity tools



CONCEPTUAL TOOL EVALUATION FRAMEWORK



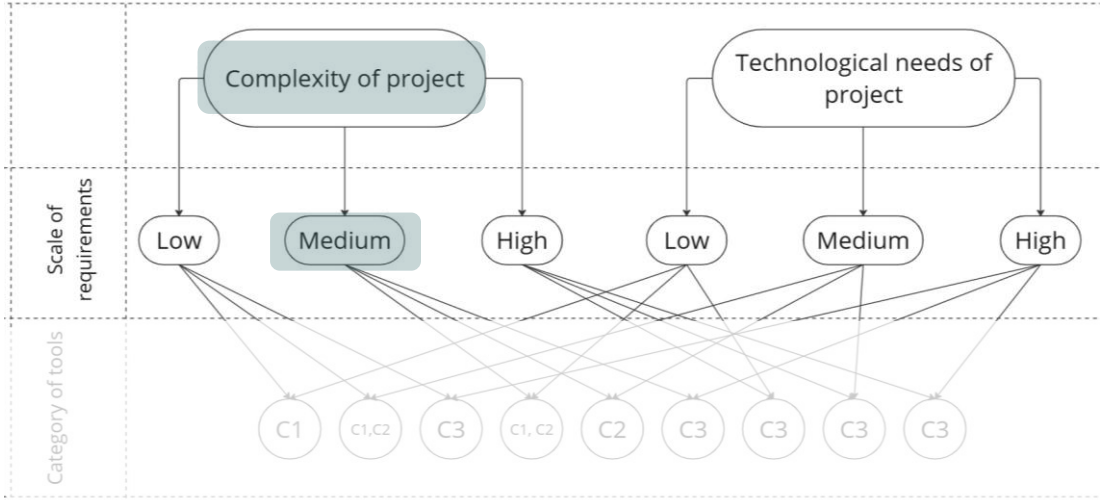
Criteria for Scale of requirements & Technological needs individually

- **Low - Simple Designs** → **C1 category tools**
- **Medium – Moderate complex designs** → **C2 category tools**
- **High – Higher complex designs** → **C3 category tools**

Criteria for Category of tools

Feature	C1: Standalone Tools (Fragmented)	C2: Collaboration Suites (Centralized)	C3: Asset Management Platforms (Operational Lifecycle)
What they are	Dedicated software designed for a specific function, operating independently without connecting to a central database.	A suite of applications that share a centralized database, allowing instant data flow between modules.	A system focused on tracking assets throughout their lifetime from commissioning to disposal.
Primary Data Goal	Task Completion	Project Coordination & Handover Readiness	Long-term Facility Management
Tool Examples	Gmail, Google drive, MS office, BIM individual softwares with openBIM formats	ERP, ACC, Aconex	CxAlloy, Ecodomus

Sample 1- If the client wants to decide from one factor – complexity of project only, and it is medium then



Complexity of Project (physical/organizational intricacy: MEP density, number of stakeholders, project scale)

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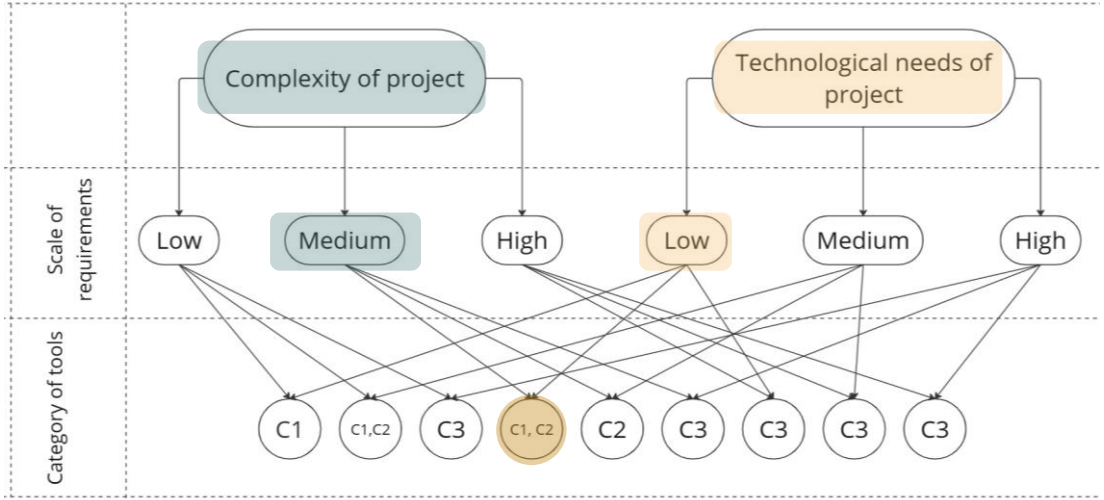
Tool Examples	Gmail, Google drive, MS office, Autodesk softwares with openBIM formats	ERP solution, ACC, Aconex	CxAlloy, Ecodomus

Sample 2- If the client wants to decide by considering both factors, then



It tells that the client can use C1 category tools, but with openBIM formats for better integration with collaboration suites as well

Criteria for Scale of requirements & Technological needs individually

Low - Simple Designs	→ C1 category tools
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KEY FINDINGS AND CONCLUSION

- The framework is useful for the clients focusing on small to medium scaled projects only
- Financial feasibility and data safety of a particular software are interdependent factors; if data safety is priority, then it won't be cost efficient. With increasing prices of the tools data safety automatically comes with it
- Factors identified changes as per the nature of project. For government project the priorities will be different as budget is not a bigger constraint, data safety is first priority
- By aligning identified factors from interviews with specific categories of digital tools, the study provides a scalable logic that helps project owners select the most appropriate tools based on their technological needs which will be easy to adapt for the project teams. This contribution ensures that even in resource-constrained private sectors, organizations can minimize information loss and achieve operational readiness.