Integrated BIM Project: The role of Digital Collaboration

Master of Science in BIM and Digital Built Environment
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December 2024, Manchester

Integrated BIM Projects

The role of Digital Collaboration

University of Salford
Manchester

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(~ 6200 words used)

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What to Expect

List of Figures and Tables

• List of Figures

• List of Tables

Abbreviations and Acronyms

Abbreviation or acronym	Term
AEC	Architecture, Engineering, and Construction
AI	Artificial Intelligence
AR	Augmented Reality
BIM	Building Information Modeling
CDE	Common Data Environment
COBie	Construction Operations Building Information Exchange
DBB	Design-Bid-Build
GLA	Global Location Number
GTIN	Global Trade Item Number
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
LC	Lean Construction
ISO	International Organization for Standardization
NIBS	National Institute of Building Sciences
PAS	Publicly Available Specification
SMEs	Small and Medium-sized Enterprises
VDC	Virtual Design and Construction
VHT	Vestfold Hospital Trust
VR	Virtual Reality

Table 1. Abbreviations and acronyms

Abstract

In the Architecture, Engineering, and Construction (AEC) sector, where fragmented workflows and segregated operations typically lead to inefficiencies, delays, and cost overruns, collaboration has long presented substantial hurdles for successful project execution. Reducing waste and improving project outcomes need smooth cooperation between many parties. Using tools like Building Information Modelling (BIM), shared data environments, and cutting-edge technology like artificial intelligence (AI), digital collaboration has recently become a crucial enabler of integrated project delivery. Digital cooperation has the potential to revolutionise the industry, but its widespread adoption is hampered by interoperability problems, skill shortages, and resistance to change.

In this study, the importance of digital collaboration for successful project delivery is examined, along with how it fits into frameworks like Integrated Project Delivery (IPD) and Lean Construction. Based on a literature review, case study and interviews with professionals in the field, the study looks at the factors that encourage, hinder, and facilitate the adoption of an integrated project delivery approach. The results offer valuable perspectives and suggestions for cultivating an environment of effectiveness, cooperation, and creativity in the AEC industry.

1. Introduction

Building vital infrastructure has always been a key function of the construction sector in economic growth. Due to the historical reliance on manual procedures and disjointed workflows, construction has frequently experienced delays, cost overruns, and serious stakeholder communication breakdowns (Ashworth, 2010). The lack of integrated, data-driven techniques and the discrete project stages in this old approach frequently led to inefficiencies, misunderstandings, and mistakes (Kibert, 2016). Figure 1 shows the significant turning points in the UK that have occurred during the shift from this conventional age to contemporary, digitalised construction techniques.

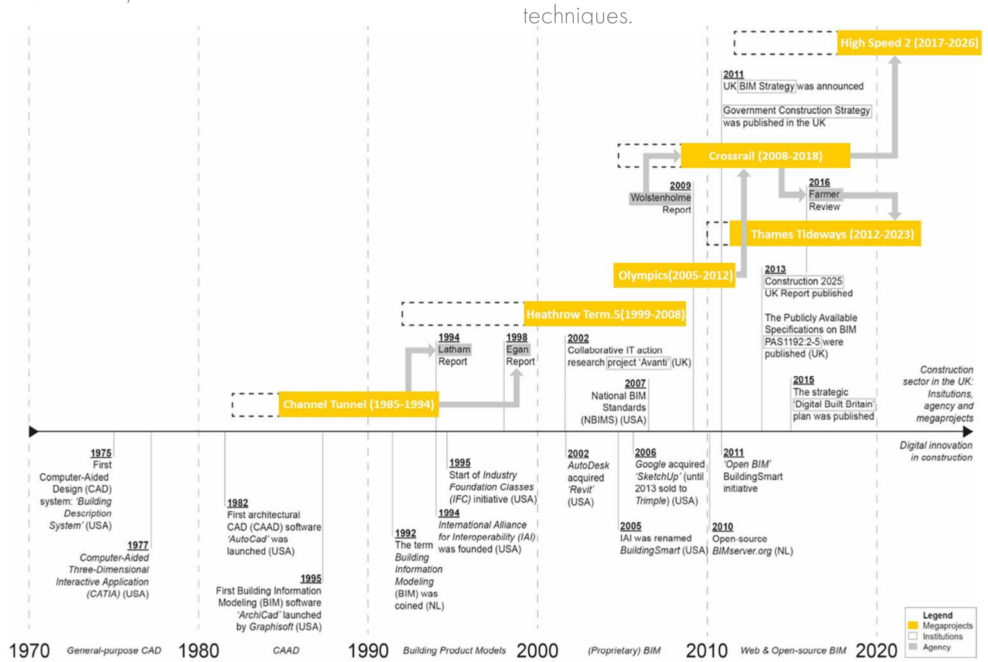

Figure 1. Timeline of digital innovation in construction influencing and being influenced by megaprojects, institutions and agency in the UK. Source: Morgan and Papadonikolaki, 2018.

A significant change in the construction sector was brought about by the advent of Computer-Aided Design (CAD) software, which made it possible to digitise the design process. Widespread adoption of CAD in the late 20th century increased design accuracy, boosted visualisation, and sped up the creation of intricate drawings (Eastman et al., 2011). In addition to boosting output, this invention provided early chances for design teams to work together. Although CAD increased individual productivity, it was unable to solve the general fragmentation in project delivery and did not provide integrated workflows across multiple disciplines, as the timeline makes clear (Egbu & Botterill, 2002).

BIM revolutionized how projects were delivered by breaking through the limited ways in which CAD was harnessed in support of the collaboration of design. The rich data environment in BIM allows various stakeholders to have a common model, hence enhancing coordination, design accuracy, and lifecycle support (Succar, 2009; Smith, 2014). BIM's alignment with Lean Construction principles, emphasizing value maximization and waste reduction via stakeholder engagement, highlights its transformative potential (Koskela, 1992). Integrating BIM with Lean has helped businesses cut redundancies and manage project complexities better (Azhar et al., 2012).

Additionally, Integrated Project Delivery (IPD), which aligns stakeholder objectives, encourages early participation of important players, and distributes risks and benefits among all stakeholders, is intimately linked to BIM (Kent & Becerik-Gerber, 2010). Integrating BIM with Lean and IPD concepts creates a cooperative project environment where openness, trust, and communication improve project productivity and creativity. Despite these obvious benefits, many organisations have not yet fully embraced BIM because of enduring obstacles such as high technology costs, skill shortages, aversion to change, and interoperability issues (Ghaffarianhoseini et al., 2017; Zuppa et al., 2017).

The integration of AI and machine learning into the system is revolutionizing the construction industry. AI solutions improve predictive analytics, automation of tasks, and real-time insight into improvements in safety and efficiencies (Sacks et al., 2020). Such development propels and promotes innovation, further enhancing efficiency throughout the project cycle, starting from design up to facility management, as noted by Bilal et al. (2016). Realizing AI's potential necessitates overcoming major barriers, particularly for firms lacking BIM adoption or digital expertise (Hamledari & Fischer, 2021).

Despite the benefits of digital tools like BIM and AI, the Architecture, Engineering, and Construction (AEC) industry faces significant challenges in digital collaboration. These include resistance to new technologies, skills shortages, software interoperability issues, and the high costs of adopting and maintaining advanced tools (Eadie et al., 2013; Ghaffarianhoseini et al., 2017). This paper examines these challenges in delivering integrated BIM projects and explores the potential for fostering a collaborative, digitally driven project delivery culture in the construction industry.

2. Literature Review

2.1. Building Information Modeling (BIM)

2.1.1 Introduction to BIM

BIM has transformed the construction industry, addressing inefficiencies through innovative solutions. Originating from CAD and early data modeling efforts, the term "BIM" emerged in the 1990s (Eastman et al., 2011). Mordue, Swaddle, and Philip (2016) describe BIM as a method combining technology and information to create a dynamic digital representation evolving with the physical project. Correspondingly, the National Institute of Building Sciences defined BIM in 2007 as "a shared digital representation that allows for informed decision-making regarding a facility from its conception to demolition or repurposing." These definitions underpin how much collaboration plays a part in BIM, along with standardized data exchange.

2.1.2 BIM Uses

Building Information Modeling (BIM) is employed throughout a project's lifecycle, targeting objectives like design visualization, cost estimation, construction planning, and facility management (Eastman et al., 2018). Kreider & Messner (2013) and the BIM Project Execution Planning Guide (2011) emphasize that BIM applications align with phase-specific goals, enhancing project efficiency, reducing errors, and supporting lifecycle management (Penn State, 2011). BIM dimensions include 3D visualization, 4D scheduling, 5D cost estimation, 6D facility management, and 7D sustainability, each adding functionality to optimize outcomes (Hamil, 2021). This structured approach ensures BIM's effectiveness across project stages.

2.1.3 BIM Maturity Levels

According to Eastman et al. (2018) and Succar (2009), BIM maturity evolves from basic 2D CAD (Level 0) to fully collaborative environments (Level 3) as shown in Figure 2. Level 1 supports limited 3D CAD within a Common Data Environment, while Level 2 emphasizes federated models and data sharing via standards like IFC and COBie. Level 3, or "Open BIM," fosters real-time collaboration, reducing data conflicts (Eastman et al., 2018). However, resistance to change, skill shortages, high costs,

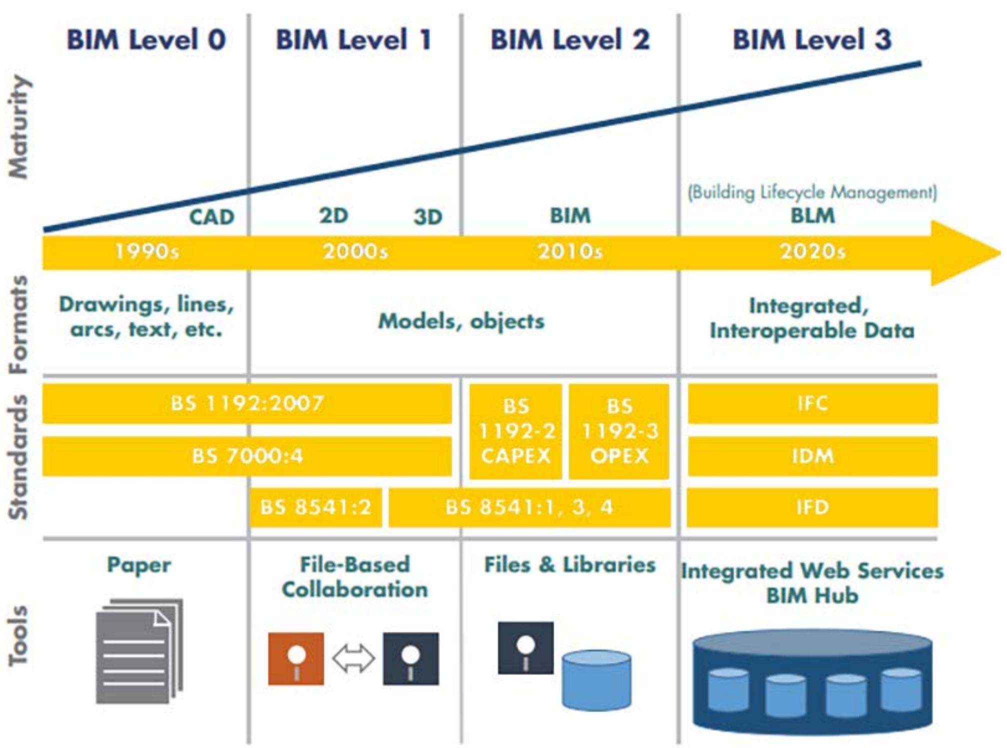

Figure 2. The BIM maturity model by Mark Bew and Mervyn Richards. Source: Eastman et al., 2018

and interoperability challenges—particularly for SMEs—make Level 3 implementation rare (Eadie et al., 2013; Ghaffarianhoseini et al., 2017). These obstacles underscore the gap between BIM's theoretical potential and practical adoption (buildingSMART, 2013). The relationship between BIM maturity, standards, and tools is illustrated in Figure 2.

2.1.4 The Role of BIM Standards in Implementation

Standards such as ISO 19650 and PAS 1192 are vital for BIM implementation, establishing protocols for data management and standard processes throughout a project's lifecycle (British Standards Institution, 2018). ISO 19650 expands on PAS 1192 (see Figure 3), offering a global framework that promotes a Common Data Environment (CDE) to enhance collaboration and minimize fragmentation among stakeholders. Implementing these standards demands considerable investment in technology, training, and changes, which is challenging for SMEs (Khosrowshahi & Arayici, 2012). Although PAS 1192 established a strong base, moving to ISO 19650 highlighted issues like inconsistent adoption and resistance (Eadie et al., 2013).

Figure 3. UK transition of ISO standards. source: RickieJ, 2019.

2.1.5 Open BIM vs. Closed BIM

Open BIM utilizes the Industry Foundation Classes (IFC) that enhance interoperability with increased sharing of data between different platforms (buildingSMART 2013). It is however not largely adopted due to issues such as software incompatibility, fragmentation of practices and high costs. Because of this most firms use Closed BIM systems that have full control internally while limiting cross-platform sharing of information (Eastman et al., 2018). This paradox shows how proprietary systems cause fragmentation. Solving these issues needs technical innovation, cultural change, vendor support, and training to realize BIM's full collaborative potential (Ghaffarianhoseini et al., 2017).

2.1.6 Benefits of BIM Implementation

BIM enhances construction project collaboration and communication by providing a centralized, data-rich model for stakeholders, reducing errors, rework, and enabling real-time decision-making (Azhar, 2011; Eastman et al., 2018). Features like clash detection and integration of design and construction data improve efficiency and cut costs (Sacks et al., 2010). BIM's potential extends to lifecycle asset management through "digital twins," which optimize operations, sustainability, and energy modeling (Khosrowshahi & Arayici, 2012; Chong et al., 2017). However, interoperability issues, cultural resistance, and significant training investments must be addressed for full adoption and lifecycle benefits (Ghaffarianhoseini et al., 2017).

2.1.7 Challenges in BIM Adoption

BIM adoption faces challenges like high initial costs for software, hardware, and training, especially for Small and Medium-sized Enterprises (SMEs) (Eadie et al., 2013). Its complexity demands specialized training, leading to a skills shortage (Khosrowshahi & Arayici, 2012). Cultural resistance to moving from traditional workflows complicates implementation (Ghaffarianhoseini et al., 2017).
Interoperability is paramount; incompatible soft-

ware sets up data silos and inefficiencies. Open standards like Industry Foundation Classes (IFC) try to at least improve data sharing, but the vendor lock-in and inconsistent implementation hinder any progress in this regard (buildingSMART, 2013). Regulatory inconsistency, even on ISO 19650, further exacerbates adoption (British Standards Institution, 2018). Overcoming these has the potential to unlock BIM's full collaborative and efficiency potential.

2.2. Lean and Digital Construction

2.2.1 Introduction to Lean Construction

Lean Construction (LC), based on the Toyota Production System, aims to enhance efficiency, cut waste, and boost value through stakeholder collaboration (Womack et al., 1990; Ballard & Howell, 2003). Its objectives include value creation, waste minimization, and continuous improvement (Green, 1999; Alves et al., 2012). LC differs from traditional methods by integrating workflows and promoting trust, transparency, and accountability. Although these benefits include reduced cost and/or faster delivery, adoption faces cultural resistance and requires systemic changes. (Koskenvesa & Koskela, 2005; Koskela & Howell, 2002).

2.2.2 Lean Construction Principles and Benefits

Lean Construction, based on Koskela's principles (see Table 2), enhances production efficiency, emphasizes lean leadership, and aligns activities with client goals to reduce waste and foster collaboration (Jayanetti et al., 2023). Benefits include improved collaboration, quality, cost savings, and timely delivery through streamlined workflows (Ballard & Howell, 2003; Womack & Jones, 1996). However, challenges like cultural resistance, fragmented practices, and the need for organizational change persist. Organizations adopting Lean often achieve greater satisfaction and success, driven by improved efficiency and innovation (Nesensohn et al., 2014).

2.2.3 Integration of Lean and BIM

The integration of Lean Construction and Building Information Modeling (BIM) enhances efficiency by combining waste minimization and continuous improvement with advanced digital modeling for better collaboration and visualization (Sacks et al., 2010). This synergy optimizes workflows, supports decision-making, and improves project outcomes (Dave et al., 2013). However, challenges like resistance to change, lack of standardized protocols, and industry fragmentation hinder practical implementation, limiting the potential effectiveness of Lean-BIM

Core Principles	Definitions
Value Generation	Aligning activities with client goals maximizes value but is challenging in multi-stakeholder settings (Ballard & Howell, 2003).
Flow Efficiency	Smooth workflows and reduced delays need careful planning and collaboration, which are tough in fragmented settings (Sacks et al., 2010).
Waste Reduction	The removal of rework and waiting is resisted by established tradition (Womack & Jones, 1996 and Sarhan & Fox, 2013).
Continuous Improvement (Kaizen)	requires strong leadership and collaboration for iterative learning and process refinement (Koskela, 2000).
Respect for People	Empowering team members and building trust is challenging in an adversarial industry (Green, 1999).

Table 2. Lean core Principles.

initiatives (Bortoluzzi et al., 2019; Edirisinghe et al., 2017). Despite these barriers, studies show Lean-BIM integration can reduce variability and improve workflow reliability (Sacks et al., 2010; Miettinen & Paavola, 2014).

2.2.4 Challenges in Implementing Lean

Implementing Lean Construction faces significant challenges, including a lack of industry knowledge leading to inappropriate applications (Vernikos et al., 2014; Nguyen et al., 2020). Traditional contracts, rigid deadlines, and varying legal constraints across states further hinder its adoption (Bygballe et al., 2018; Daramsis et al., 2018). Cultural resistance rooted in traditional norms exacerbates these difficulties, necessitating strong leadership and collaborative efforts (Monyane et al., 2018). Fragmented teams, communication barriers, and space constraints in complex projects disrupt workflows and limit Lean efficiency (Daniel et al., 2016; Wondimu et al., 2017). Simonsen (2023) in Figure 4 provides a systematic review highlighting these challenges in the public sector projects.

2.3. Integrated Project Delivery (IPD)

2.3.1 Introduction to IPD

IPD represents a transformative model for the AEC industry, addressing the fragmentation and adversarial relationships inherent in traditional methods like Design-Bid-Build (DBB). By fostering early collaboration and shared risk among stakeholders, IPD aligns incentives and enhances decision-making to optimize project outcomes (Kent & Becerik-Gerber, 2010; AIA, 2007). Advocates highlight its ability to reduce costs, improve timelines, and enhance quality (El Asmar et al., 2013). However, IPD requires

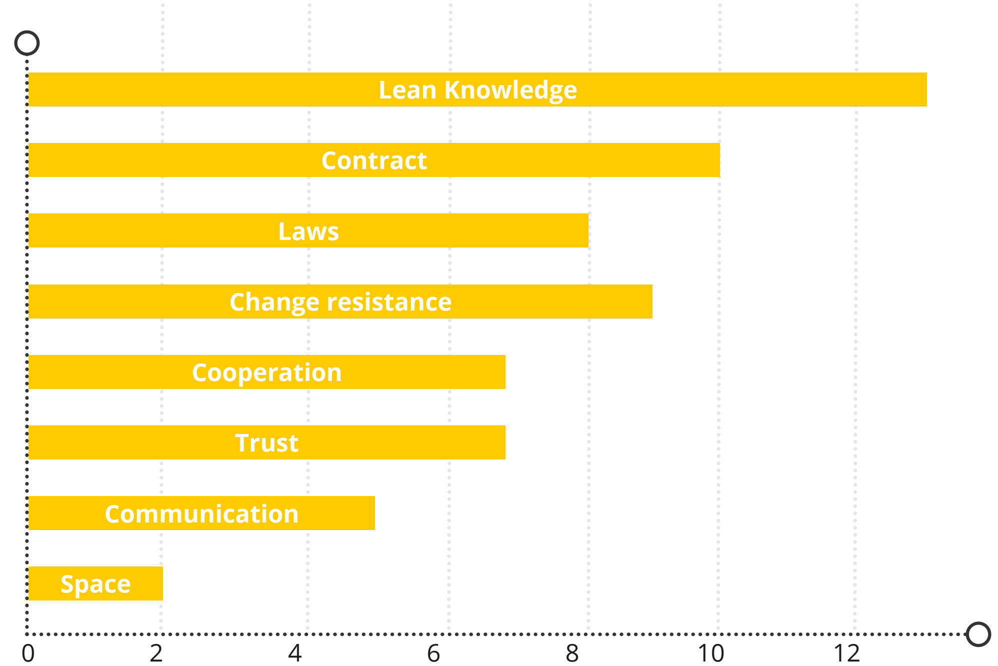

Figure 4. Graphical representation based on the difficulties present in projects in which Lean was implemented. Source: Simonsen et al., 2023

overcoming significant cultural and structural challenges, including trust-building, integrated contracts, and new leadership models, which remain hindered by entrenched practices and misaligned interests (Ghassemi & Becerik-Gerber, 2011; Mesa et al., 2019).

2.3.2 IPD Principles and Benefits

IPD emphasizes stakeholder collaboration and aligned incentives to optimize project outcomes, but its success faces systemic challenges. The shared risk and reward model aims to foster transparency and collective performance but necessitates extensive contractual restructuring and trust-building in an industry long accustomed to adversarial practices (Ashcraft, 2011; Kent & Becerik-Gerber, 2010). While multi-party agreements and joint decision-making leverage diverse expertise, they often result in conflicts and delays due to power imbalances and differing priorities (El Asmar et al., 2013). Transparency and open communication, critical for IPD, remain hindered by entrenched industry silos and resistance to information sharing, highlighting the complexity of achieving genuine integration (Ghassemi & Becerik-Gerber, 2011).The list of IPD principles are summarized into contractual & behavioral groups in Figure 5.

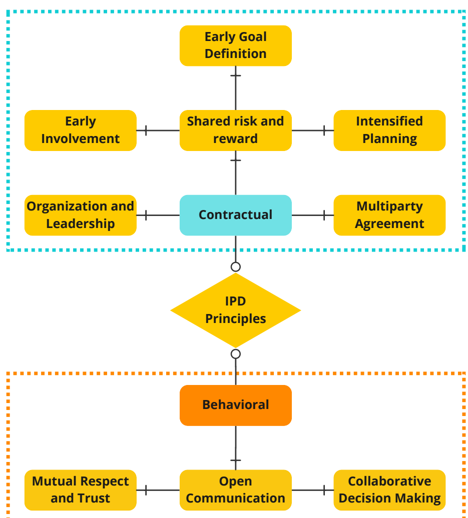

Figure 5. Integrated Project Delivery (IPD) principles, grouped as Behavioral and Contractual. Source: AIA, 2007.

2.3.3 Integration of IPD with BIM and Lean

Integrating IPD, BIM, and Lean Construction addresses fragmentation and inefficiencies in the AEC industry by improving collaboration, optimizing workflows, and reducing waste (Kent & Becerik-Gerber, 2010; El Asmar et al., 2013). However, Implementation faces barriers like non-standard frameworks, cultural resistance, high tech and training costs, and legal complexities (Ghassemi & Becerik-Gerber, 2011; Mesa et al., 2019). These challenges, particularly for smaller firms, must be addressed to unlock the full potential of these synergistic methods.

2.3.4 Challenges in Implementing IPD

IPD offers collaboration and efficiency in the AEC industry but faces significant challenges. Entrenched siloed operations and adversarial relationships resist IPD's collaborative ethos (Kent & Becerik-Gerber, 2010). Achieving integration requires complex, resource-intensive contracts and substantial investments in technology, training, and leadership development, which many organizations cannot afford (Ashcraft, 2011; El Asmar et al., 2013). The shared risk-reward model demands trust and transparency, yet the industry's compartmentalized practices hinder adoption (Ghassemi & Becerik-Gerber, 2011). Without addressing these systemic barriers, IPD's full potential remains difficult to achieve (Mesa et al., 2019).

2.4. Digital Collaboration: Enablers and Challenges

2.4.1 Introduction to Digital Collaboration

Digital collaboration is transforming the construction industry by addressing inefficiencies and fragmentation in traditional project delivery. Using digital tools and platforms, stakeholders—architects, engineers, contractors, and clients—can share data and communicate in real time, improving workflows, decision-making, and reducing errors (Eastman et al., 2018). However, entrenched silos, resistance to change, and interoperability challenges hinder its adoption (Alreshidi et al., 2017). Transparency and trust are crucial but hard to achieve in a competitive, compartmentalized industry (Succar, 2009). For its transformative potential to be realized, significant technological investments and cultural shifts are essential.

2.4.2 Enablers and Drivers of Digital Collaboration for Integrated BIM Projects

Digital collaboration will have enormous potential to realize the integrated approach to project delivery in the digital built environment. Through modern technologies and innovative frameworks, stakeholders will be able to optimize project workflows, bringing along minimized cases of inaptitude while supporting real-time collaboration.

- **Digital Twins and Other Technological Innovations**

Digital twins, along with innovations like artificial intelligence (AI), augmented reality (AR), virtual reality (VR), and common data environments (CDE), are transforming construction collaboration. Digital twins provide real-time, dynamic models of physical assets by integrating data from BIM, IoT, and sensors, facilitating lifecycle collaboration (Bolton et al., 2018; Boje et al., 2020). AI, AR, and VR enhance project planning, risk assessment, and design visualization, while CDEs improve data sharing and communication. However, interoperability issues, high implementation costs, and resistance to change remain barriers to fully leveraging these technologies (Khajavi et al., 2019; Pan & Zhang, 2021). Figure 6 the evolution of BIM drived by emerging technologies.

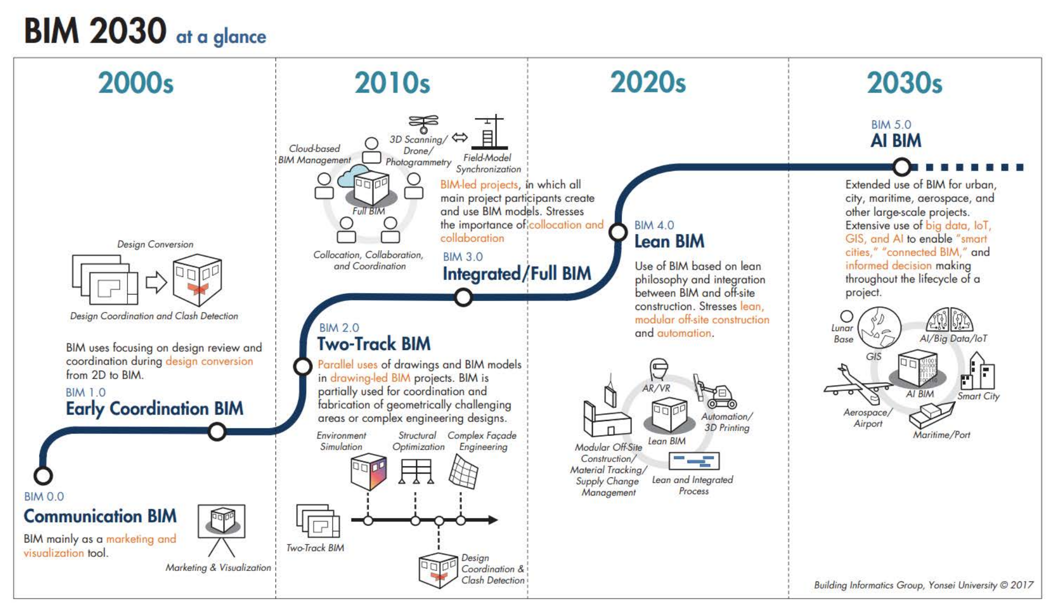

Figure 6. BIM, as a driver technology, progression through the decades. Source: Yonsei University, 2017.

- **New Roles and Responsibilities**

The adoption of digital collaboration in construction has introduced roles such as BIM Managers, Coordinators, Modelers, and Specialists to manage data exchange and support integrated workflows (Succar et al., 2013). These roles are pivotal for leveraging digital tools and fostering collaboration but present challenges in redefining accountability, adapting traditional structures, and addressing resistance from professionals hesitant to embrace changing responsibilities (Ghaffarianhoseini et al., 2017).

- **Cloud computing platforms**

Cloud computing enables digital collaboration in construction by providing scalable platforms for data sharing, storage, and real-time communication, supporting BIM processes and digital twins (Redmond et al., 2012; Alreshidi et al., 2017). It enhances workflows by breaking down traditional barriers and offering remote data access. However, challenges like data security concerns, high costs, vendor lock-in, and interoperability issues hinder adoption (Wu et al., 2017; Migliaccio et al., 2019). Despite these challenges, cloud computing remains a transformative tool for enhancing transparency, communication, and overall project efficiency.

- **Contracts and a BIM Learning Environment**

Customized contracts, like IPD agreements, are needed to encourage collaboration, alignment of incentives, and risk management in BIM projects. On the other hand, traditional contracts are usually inadequate to respond to these collaborative requirements and often need a shift in culture for the embedding of trust and transparency (Ashcraft, 2011; Mesa et al., 2019). Setting up BIM learning environments is also equally important, wherein training programs and certification provide solutions to skill gaps. However, this inequality in educational access maintains knowledge silos and thus limits the full-scale application of digital collaboration methods (Succar et al., 2013).

- **Transparencyand Trust**

Transparency and trust are the basic components of digital collaboration that allow for free sharing of information and quick decision-making using tools like BIM and integrated platforms (Kent & Becerik-Gerber, 2010; Arayici et al., 2012). However, resistance toward transparency due to fear of data security, competition, and visibility of one's mistakes after commits reflects the industry's reliance on segregation of processes (Ghaffarianhoseini et al., 2017). Fostering trust by means of strong protocols and a cooperative culture is essential for achieving the advantages associated with transparency in project execution (Linderoth, 2010).

- **Supportive regulations**

Regulatory frameworks, such as ISO 19650, are essential for enabling consistent adoption of digital technologies like BIM and digital twins by establishing standards for data management and interoperability (British Standards Institution, 2018; Kassem & Succar, 2017). However, enforcement disparities, regional inconsistencies, and balancing prescriptive requirements with innovation pose challenges. Effective regulations must evolve to accommodate technological advancements and local contexts.

2.4.3 Challenges/Barriers of Digital Collaboration for Integrated BIM Projects

- **Individual Factors**

Individual factors affect digital collaboration in construction, with challenges like resistance to change, lack of digital skills, and varied tech proficiency. Resistance arises from skepticism about new tools and fear of workflow disruptions (Succar, 2009; Ghaffarianhoseini et al., 2017). There is also a certain skills gap in the professional contribution of BIM and digital twins, underlined by Khosrowshahi & Arayici, 2012. Digital illiteracy, as a result, develops unequal collaboration in teams. Rigorous training and professional development in an outlook of culture for change and innovation can result in overcoming such issues, as noted by Alreshidi et al. (2017).

- **Environmental and Management Factors**

Digital collaboration in construction is significantly influenced by environmental and management factors. Organizational culture has often acted as a barrier to genuine collaboration because of rigid hierarchies and resistance to change (Davies & Harty, 2013; Whyte & Levitt, 2011). Collaboration thrives on leadership promoting transparency, knowledge sharing, and teamwork (Rezgui et al., 2010). Further compounding collaboration, therefore, are external factors related to inconsistent regulatory frameworks and the ensuing problems of compliance that limit resource investment of smaller firms (Kassem et al., 2015; Love et al., 2011). There is alignment of leadership, cultural transformation, and regulation that would help overcome the above challenges by adopting digital.

- **Technological Factors**

Technological innovations such as BIM and digital twin consequently enhance data integration in construction (Azhar 2011). However, several challenges persisting in construction include interoperability of software, propriety systems, and difficulties in implementing complex solutions (Whyte & Lobo 2010; Arayici et al. 2011). High software and training costs are major barriers to the adoption by smaller firms (Love et al. 2011). Sector fragmentation is worsened by inconsistent data standards, underscoring the need for open standards and improved interoperability to fully leverage these technologies (Rezgui et al., 2013).

- **Data Security**

Data security is vital in construction digital collaboration because of the widespread use of tools like BIM, cloud platforms, and digital twins that share sensitive data among stakeholders (Almukhtar et al., 2019). Access control management and protection of data are associated with a greater prospect of breach and eventual data loss-impacting project integrity. These are further complicated on cloud platforms by issues of data ownership, access control, and regulation (Beach et al., 2013; Zou et al., 2019). Cybersecurity measures like encryption and role-based access controls are underused, highlighting the need for data governance strategies that balance security and collaboration (Bilal et al., 2016).

3. Case Study: The Tonsberg Project

Tonsberg Hospital	
Location	Tonsberg, Norway
Client	Tonsbergprosjektet, Sykehuset i Vestfold
Status	Finished
Gross Area	42.000 m^2
Consultant	LINK Arkitektur
Photo	Melissa Hegge

Table 3. Tonsberg Hospital project information.

Figure 7. The Tonsberg Hospital. Source: Melissa Hegge.

3.1. Introduction

The Tonsberg project exemplifies excellence in hospital construction by integrating somatic and psychiatric care within a sustainability framework (LINK arkitektur, 2024). It prioritized collaboration and efficiency across disciplines, leveraging Integrated Project Delivery (IPD), Virtual Design and Construction (VDC), Target Value Design (TVD), Lean Construction, and Open-BIM standards. Ambitious goals included a 10% cost reduction and a 50% faster construction timeline (LINK arkitektur, 2024). Achieving zero defects at handover, a BREEAM "Very Good" rating, and a comprehensive BIM model for lifecycle management (buildingSMART International, 2017), the project earned the 2017 buildingSMART International Award for its innovative use of Open-BIM and digital collaboration tools.

3.2. BIM Utilization

The ambition of the Tonsberg project was comprehensive application of BIM within all seven dimensions; however, the practical implementation of 4D-time and 5D-cost was partial. BIM allowed paperless workflows, enhanced communication, and provided information on site via kiosks (Simonsen et al., 2019). Amongst the challenges, there were the integration of fragmented models and re-skilling, as generally experienced within the industry by Ghaffarianhoseini et al. in 2017. Effective deployment required strong leadership and training (Eadie et al., 2013). Defining model detail levels was complex, needing standardized measures. Dependence on printed drawings and lack of training showed struggles in maximizing BIM's potential for collaboration and reducing data silos (Chong et al., 2017).

3.3. Lean Construction Integration

The Tonsberg project used Lean Construction principles through Integrated Project Delivery (IPD), focusing on Target Value Design (TVD) and the Last Planner System (LPS) to improve value and control costs. TVD aligned goals with cost criteria through frequent reviews, but design delays complicated on-site work, revealing implementation challenges (Ashcraft, 2011; Zimina et al., 2012). Still, TVD was key in achieving financial goals and engaging stakeholders. LPS enhanced production control through multi-tiered scheduling and digital tools, highlighting Lean's effectiveness. Yet, achieving Lean's collaborative efficiencies needed overcoming old practices and distinguishing IPD from traditional methods (Simonsen et al., 2019).

3.4. IPD Implementation

The Tonsberg project showcases Integrated Project Delivery (IPD) via contracts and behavior. Early engagement of owners, designers, and contractors enhanced cost control and reduced risks but struggled with team engagement (Fischer et al., 2017; Simonsen et al., 2019). The shared risk-reward system promoted collaboration but revealed issues with risk distribution and cost agreements (Pishdad-Bozorgi & Beliveau, 2016). The multiparty agreement, designed for Norwegian laws, facilitated flexible collaboration despite early challenges. Trust improved cohesion, yet clear roles and vertical alignment are still needed for effectiveness (Simonsen et al., 2019).

3.5. Digital collaboration, Tools and Workflows

The Tonsberg project demonstrated both the potential and challenges of digital collaboration in complex construction through integrated BIM and tools for enhanced coordination. Jotne's BIM server and buildingSMART's openBIM standards allow for centralized data exchange, digital twin creation, and real-time updates, using standardized identifiers such as Global Trade Item Number (GTIN) and Global Location Number (GLN) for product traceability (Godager et al. 2024). Challenges included fragmented workflows, manual documentation, and delayed product registration, with limited ISO 19650 adoption, highlighting difficulties in integrating disparate data systems in high-BIM-ambition projects (Skoglund & Simonsen, 2019; Aarseth, 2020; buildingSMART, 2017). Figure 8 shows the tools used and the BIM workflow for the project.

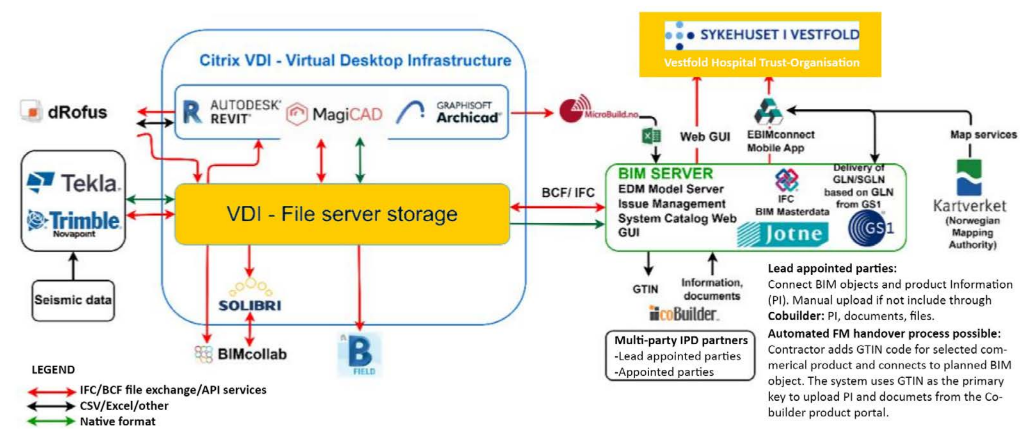

Figure 8. Planned BIM technology map description for the Tonsberg project and the handover in the project at Vestfold Hospital Trust (VHT). Source: Jotne, Aarseth, 2020.

4. Research Methodology

4.1. Research Design

The study uses a mixed-methods approach, combining qualitative and case studies to explore the enablers and challenges of Integrated BIM Project Delivery in the AEC sector. This method allows for a comprehensive analysis of the complex factors affecting collaboration (Creswell & Plano Clark, 2018). This design encompasses a literature review, a case study, and semi-structured interviews with experts from the involved industry.

4.2. Literature Review

The literature review serves as the foundational element, synthesizing existing scholarly work on digital collaboration, BIM, Lean Construction, and Integrated Project Delivery (IPD). Academic books, peer-reviewed journals, and standards such as ISO 19650 were analyzed to contextualize and identify gaps in the understanding of integrated project delivery practices and their digital enablers.

4.3. Case Study

The Tonsberg project is a hospital building project where heavy use of IPD, BIM, and digital tools is made. It was selected for this research in order to provide insight into the answers to the research questions, mainly because of its innovative use of Open-BIM and Lean principles. Data collection is going to be done through project reports, documentation, and observation of successes, problems, and lessons learned.

4.4. Semi-Structured Interviews

Semi-structured interviews with AEC professionals provided rich responses regarding digital collaboration and integrated BIM projects. This approach was flexible, allowing deep explorations of the participants' experiences and contextual factors influencing collaboration (Bryman, 2015). The questions (see Appendix D) aligned with the three main research questions:

- What is an integrated approach to project delivery in the context of the digital built environment?
- What are the key drivers/enablers for and challenges/barriers?
- What is the potential and way forward for an integrated approach to project delivery becoming business as usual and accepted industry norm?

The selection was done because these respondents have experience in integrated BIM projects and digital collaboration.

- BIM Manager (More than 15 years in AEC industry) based in Norway.
- Architect and Digital lead (More than 10 years in AEC industry) based in London, England.

Interviews were conducted (see interview summary at Appendix E) via Microsoft Teams in December 2024, each lasting approximately one hour. The recorded data, alongside secondary data collected, was utilized in the data analysis section to provide comprehensive insights and support the research findings.

5. Data Analysis

5.1. Challenges of Digital Collaboration to Deliver Integrated Projects

5.1.1 Resistance to Change

Resistance to digital collaboration tools in the AEC industry stems from traditional workflows and cultural inertia. Skepticism toward new technologies and perceived complexity are significant barriers (Succar, 2009; Ghaffarianhoseini et al., 2017). On the Tonsberg project, the stakeholders relied on printed drawings, and fragmented work processes impeded fully digital collaboration and application of standards like ISO 19650 (Skoglund & Simonsen, 2019; Aarseth, 2020).

Participants confirmed these results. P1 pointed out the resistance to change: ***"people are very conservative. It's not easy to introduce new platforms. The way I addressed challenges was to reduce the number of new tools for them, to be persistent, listen to their concerns, and empathize with their point of view."*** Similarly, the resistance to change from organizational side: ***"we've faced situations where senior managers refused to adopt new tools because they felt the learning curve was too steep. This resistance slows down the entire team's progress."*** From these views, it becomes clear that in both levels (individual and organizational), it hinders progress.

Moreover, Literature and case studies indicate that resistance is a matter of cultural challenge that requires strategic intervention through empathetic leadership, smoothing of workflow processes, and continuous stakeholder engagement in building trust for the adoption of digital tools.

5.1.2 Technological challenges

Technological challenges hinder digital collaboration tool adoption in the AEC industry. High software, hardware, and training costs impact SMEs, while software interoperability and rapid advancements lead to fragmented workflows (Eadie et al., 2013; Whyte & Lobo, 2010). The Tonsberg project struggled with these issues, facing integration problems and inconsistent standards (Simonsen et al., 2019).

Interview insights emphasize these challenges more. P1 explained that software updates are very frustrating and stand in the way of working on and accessing the models: ***"the biggest challenge we face is with software updates—they sometimes disrupt access to models for hours, which can halt workflows."*** He added cost issues by saying ***"...most tools are very expensive, making them inaccessible for smaller firms."*** Moreover, P2 noticed interoperability issues, which makes them revert to manual workflows, adding costs and delays ***"The biggest challenge we face is ensuring interoperability across tools...."*** P2 also fully acknowledges how software updates are a drag in workflow: ***"Even with open standards like IFC, interoperability issues force us to resort to manual workarounds, and keeping tools updated adds to the burden."***

Evidence of how inconsistency in implementation, high costs, and speed of advancement impede effective technological integration into digital collaboration, despite solutions provided through open standards such as IFC and ISO 19650.

5.1.3 Skill and Knowledge gaps

Skill and knowledge gaps hinder the AEC industry's adoption of digital collaboration tools. Most collaboration is hindered by a lack of expertise in technologies such as BIM and Lean principles, which introduces inefficiencies (Khosrowshahi & Arayici, 2012; Vernikos et al., 2014). In the case study presented, it can be observed that dependence on printed drawings and a lack of proper training further limit what BIM has to offer for enhancing collaboration (Chong et al., 2017).

P1 agreed with the competency gaps: ***"many clients don't have BIM resources—they don't have BIM coordinators or BIM managers in their companies. You can hire a consultant, but they don't always act in the company's best interest."*** P2 identified the shortage of experienced BIM personnel impact: ***"the shortage of qualified BIM professionals makes it difficult to scale up operations, especially with complex projects."*** These gaps indicate that industry stakeholders should invest more in the training, certification, and professional development that these effective digital collaboration technologies require.

5.2. Barriers of Digital Collaboration

5.2.1 Organizational Silos

Organizational silos driven by proprietary software reliance in the AEC industry result in reduced digital collaboration since poor data exchange causes fragmented workflows. Sometimes, interoperability is still an issue at times even with the use of Open BIM-as recently demonstrated in the Tonsberg project where stakeholders experienced unification problems because of the limited capability of the tools involved (Simonsen et al., 2019).

P1 explained that as long as stakeholders relied on proprietary software, data silos would exist, meaning that even with Open BIM standards: ***"...data silos still exist when stakeholders rely on proprietary software. Even with Open BIM standards, some tools don't integrate seamlessly."*** In the same light, P2 argued that interoperability challenges force manual workarounds, slowing processes: ***"proprietary software still causes issues... It's frustrating when two tools don't integrate, forcing us to resort to manual workarounds."*** Therefore, these silos can only be resolved by the more pervasive use of open standards such as IFC, interoperable tools, and collaborative culture for better integrated project delivery.

5.2.2 Data Security Concerns

Data security is a major challenge in AEC digital collaboration, requiring sensitive information sharing among stakeholders through tools like BIM and cloud platforms. Almukhtar et al. (2019) highlight the need for secure access control and strong data protection to avoid breaches that threaten project integrity. Cloud platforms complicate data security management due to data ownership, access control, and regulatory compliance issues, creating more vulnerabilities (Beach et al., 2013; Zou et al., 2019). P1 felt concerned about cloud platforms: ***"the reliance on cloud platforms raises concerns about data security, especially when sensitive project information is shared across multiple stakeholders without clear protocols for access control."*** P2 had less critical security requirements in mind and emphasized the issue of mere precautionary measures: ***"we try to apply access controls to ensure only authorized stakeholders can modify or view specific data. It's a basic precaution that adds an extra layer of accountability."*** Therefore, addressing these issue's needs, comprehensive access controls, encryption, and regulatory compliance remain cardinal prerequisites to enabling secure digital collaboration.

5.3. Drivers of Digital Collaboration

5.3.1 Emerging technologies

Emerging technologies like Digital twins, Artificial Intelligence (AI), Augmented Reality (AR), and Virtual Reality (VR) are transforming construction by enhancing workflows, decision-making, and lifecycle management through real-time data integration from BIM, IoT devices, and sensors (Bolton et al., 2018; Boje et al., 2020). Digital twins connects design, construction, and operation, thus improving the monitoring of assets post-construction, as explained by P1: ***"Digital twins have revolutionized how we manage assets. By integrating real-time data from IoT devices, we can monitor the performance of a building even after project completion."***

AI automates repetitive tasks and increases precision, as was remarked by P1: ***"We use a lot of AI, especially with tunneling, and I also use it in my own role for many, many things that I do."*** P2 gave examples of how AI takes care of clash detection and AR offers clients immersive visualization: ***"emerging technologies like AI and AR are becoming part of our workflow. AI is particularly helpful in automating clash detection, while AR provides immersive visualization for clients."*** These technologies enhance innovation and productivity, yet most challenges for interoperability, skill gaps, and resistance to change have to be overcome for complete integration with AEC workflows.

5.3.2 Leadership and Training

Leadership and training are critical enablers of digital collaboration in the construction industry, ensuring that cultural shifts accompany technological adoption. Effective leadership not only champions innovation but also creates an environment where teams are supported in embracing digital tools without fear of failure (Rezgui et al., 2010). P1 emphasized the role of leadership in fostering confidence within teams: ***"Our leadership team actively supports digital transformation, which creates an environment where teams feel confident exploring new tools without fear of being penalized for mistakes."***

P2 reinforced this point, highlighting leadership's role in prioritizing training and innovation: ***"the role of leadership in digital transformation is underestimated. Our leaders advocate for innovation and allocate time for training, which has been key to successful tool adoption across teams."*** These insights underscore the importance of leadership in setting a vision for transformation while providing the necessary resources and support.

Moreover, training programs and certifications help bridge skill gaps, but unequal access to educational resources can perpetuate knowledge silos, limiting broader adoption of digital collaboration methods (Succar et al., 2013). Strong leadership is thus essential not only for driving cultural changes but also for ensuring equitable access to training and development opportunities across teams.

5.4. Enablers of Digital Collaboration

5.4.1 BIM and Open BIM

Building Information Modeling (BIM) has transformed construction through a shared, data-rich environment that boosts collaboration and design accuracy while minimizing inefficiencies and rework (Succar, 2009; Koskela, 1992). Open BIM, backed by standards like IFC, improves interoperability for seamless data exchange and global collaboration (Azhar, 2011; Eastman et al., 2018).

P1 then supported the idea by listing the on-site advantages of BIM: ***"The introduction of BIM kiosks and mobile devices on-site has allowed team members to retrieve the latest drawings or models immediately, eliminating delays caused by waiting for printed updates."*** He further added that Open BIM enhances collaboration: ***"We rely on open BIM standards like IFC and tools such as Revit and Tekla Structures to exchange data seamlessly."***

P2, in turn, underlined the possibility of international teamwork supported by Open BIM: ***"Open BIM has been a game-changer for us. It allows us to work with international teams without worrying about proprietary software compatibility."*** However, he mentioned that a partial lack of understanding is holding back the thorough potential. Even though BIM and Open BIM are driving improvements, full adoption is faced with challenges such as standardization and training. Their ability to improve coordination and support integrated project delivery is evident.

5.4.2 Cloud Platforms

Cloud computing has transformed construction collaboration with centralized, scalable platforms for real-time data sharing, supporting workflows like BIM and digital twin creation (Redmond et al., 2012; Alreshidi et al., 2017). The Tonsberg project exemplified this with Jotne's BIM server, enabling centralized data exchange and real-time updates, improving coordination (Godager et al., 2024).

P2 valued the efficiency gained from using Autodesk Construction Cloud but noted interoperability issues with older desktop tools: ***"these tools are really good in collaboration but have*** *problems exchanging data with legacy systems."* Exuberance with collaboration increases through cloud platforms, although many companies are throttled by legacy systems and spotty adoption. Regardless, the future of digitized workflows in construction depends on cloud platforms.

5.4.3 Transparency and Trust

Transparency and trust are vital for digital collaboration, fostering open communication and swift decision-making with tools like BIM (Kent & Becerik-Gerber, 2010; Arayici et al., 2012). P1 stressed trust in introducing new tools: *"without trust, transparency is impossible, and teams will revert to old methods."* Similarly, P2 added that for trust, collaboration takes some time in: *"demonstrating the value of transparency is essential."* While transparency improves alignment by reducing miscommunication, building trust overcomes resistance and silos.

6. Conclusion

This research has explored the multilevel role of digital collaboration for delivering integrated BIM projects, showing linkages to challenges, barriers, drivers, enablers, and opportunities. It also identified that digital collaboration could cause an exciting revolution in the AEC industry, which is impeded by resistance to change, technical problems, skill deficits, organizational silos, and concerns on data security. This has been exacerbated by the traditional fragmentation of the industry, added to by major financial investments in upgrading technology, training, and cultural change.

All these challenges notwithstanding, digital collaboration is empowered with the advent of enabling technologies: digital twins, artificial intelligence, and augmented reality, hence assuring much better decision-making and much higher efficiency. Innovation at leadership and in training, followed by Open BIM and cloud platforms, creates better interoperability and real-time communication. Transparency and trust create collaboration based on open information, hence making each one responsible.

Practitioners' views and the case of the T nsberg project bring forward some practical issues and advantages of digital collaboration. It has brought into light the transformational potency of BIM, Lean, and IPD while showing shortcomings in the realms of competency, interoperability, and preparedness for cultural change.

This necessitates total digital collaboration in integrated BIM projects through a culture of sharing, investing in skills, and interoperability with open standards such as IFC. Bold steps in trust and data transparency will again be required but with data governance and security. Applications of the next wave of new technologies include leveraging AI, AR, and digital twins. Regulation framing based on standards like ISO 19650 enables better harmonization and interoperability, increasing collaboration toward a more effective and sustainable future in integrated project delivery.

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8. Appendices

8.1. Glossary of Key Terms

Term	Definition
BIM (Building Information Modeling)	BIM (Building Information Modeling) A process that integrates technology and information to create a shared digital representation of a project's lifecycle, enabling collaboration, reducing errors, and enhancing efficiency. BIM supports visualization, planning, and lifecycle management (Eastman et al., 2018).
Open BIM	Open BIM Refers to the use of non-proprietary, standardized formats like IFC (Industry Foundation Classes) to facilitate seamless data exchange and collaboration across diverse stakeholders and platforms, promoting interoperability (buildingSMART, 2013).
Closed BIM	Closed BIM A BIM methodology where data and models are exchanged only within a single proprietary software ecosystem, often limiting cross-disciplinary collaboration but offering better control over internal workflows (Eastman et al., 2011).
BIM Uses	BIM Uses Applications of BIM throughout a project's lifecycle, including design visualization, cost estimation (5D), scheduling (4D), and facility management (6D). These uses enhance collaboration, reduce errors, and optimize project outcomes (Kreider & Messner, 2013).
BIM Maturity Levels	BIM Maturity Levels Levels of BIM adoption: Level 1 focuses on 3D CAD in a Common Data Environment (CDE); Level 2 adds federated models and data-sharing standards like IFC and COBie; Level 3 ("Open BIM") achieves real-time collaboration with minimal data conflict (Succar, 2009).
IFC (Industry Foundation Classes)	IFC (Industry Foundation Classes) A standardized, non-proprietary data format that enables interoperability between different software tools in the BIM process. It allows the exchange of model data without being tied to a single vendor (buildingSMART, 2013).
ISO 19650	ISO 19650 An international standard for managing information over the lifecycle of a built asset using BIM. It consists of five parts: Organization of Information (Part 1), Delivery Phase (Part 2), Operational Phase (Part 3), Information Exchange (Part 4), and Security (Part 5) (British Standards Institution, 2018).
ISO 19650-1	ISO 19650-1 Focuses on concepts and principles for organizing and digitizing information about buildings and civil engineering works, including BIM.
ISO 19650-2	ISO 19650-2 Details the requirements for information management during the delivery phase of construction projects, including coordination and collaboration using BIM.
ISO 19650-3	ISO 19650-3 Provides guidance for information management during the operational phase of built assets, emphasizing lifecycle data management.
ISO 19650-4	ISO 19650-4 Specifies information exchange requirements, including formats, workflows, and data sharing protocols to ensure smooth collaboration among stakeholders.
ISO 19650-5	ISO 19650-5 Addresses security-minded information management, offering guidelines to protect sensitive data throughout the asset's lifecycle.
Digital Twin	Digital Twin A dynamic, real-time digital replica of a physical asset, integrating data from BIM, IoT sensors, and other sources. Digital twins support monitoring, decision-making, and lifecycle management (Bolton et al., 2018; Boje et al., 2020).
Lean Construction (LC)	Lean Construction (LC) A methodology adapted from Lean manufacturing, focusing on maximizing value, minimizing waste, and promoting continuous improvement. LC fosters collaboration among stakeholders and enhances efficiency in project delivery (Womack et al., 1990; Ballard & Howell, 2003).
Integrated Project Delivery (IPD)	Integrated Project Delivery (IPD) A collaborative project delivery method emphasizing early stakeholder involvement, shared risk, and aligned incentives. IPD aims to optimize project outcomes by fostering trust and transparency (Kent & Becerik-Gerber, 2010; Ashcraft, 2011).
Common Data Environment (CDE)	Common Data Environment (CDE) A shared digital repository used to manage, store, and exchange project information, ensuring data consistency and accessibility for all stakeholders throughout the project lifecycle (British Standards Institution, 2018).
4D BIM	4D BIM Incorporates time-related data into the BIM model to support construction scheduling and project visualization over time, enabling improved planning and sequencing (Eastman et al., 2018).
5D BIM	5D BIM Adds cost estimation capabilities to the BIM model, allowing stakeholders to link project budgets and financial analysis to the design and construction phases (Kreider & Messner, 2013).
6D BIM	6D BIM Extends BIM functionality to facility management, enabling lifecycle management, energy modeling, and sustainability analyses for optimized asset performance (Eastman et al., 2018).
7D BIM	7D BIM Focuses on the integration of sustainability data into the BIM model, supporting energy efficiency and environmental impact assessments throughout the asset's lifecycle (Hamil, 2021).
Artificial Intelligence (AI)	Artificial Intelligence (AI) AI technologies in construction aid in predictive analytics, clash detection, and optimization of workflows, contributing to improved decision-making and operational efficiency (Khajavi et al., 2019).
Augmented Reality (AR)	Augmented Reality (AR) Enhances real-world environments with virtual information, supporting immersive design visualization and on-site guidance during construction (Boje et al., 2020).
Virtual Reality (VR)	Virtual Reality (VR) Provides fully immersive virtual environments for project visualization, enabling stakeholders to explore and assess designs before construction (Pan & Zhang, 2021).
Cloud Computing	Cloud Computing Offers scalable platforms for real-time data sharing and collaboration in construction, supporting integrated workflows and BIM processes. Challenges include data security concerns and interoperability issues (Redmond et al., 2012; Alreshidi et al., 2017).

Table 4. Glossary of key terms used in this paper.

8.2. Participant Brief

University of Salford
MANCHESTER

<u>MSc. BIM & Digital Built Environments</u>

<u>Integrated BIM Projects Assignment Participant Brief</u>

Name: Solomon Tesfaye

Institution: University of Salford

I am currently undertaking an MSc. in BIM & Digital Built Environments. As part of my assignment for the Integrated BIM Projects module I am tasked with exploring BIM and Lean in the context of an integrated approach to project delivery.

I have approached you to participate in the study as an industry practitioner in order to gain your views and perspective into BIM, Lean, and an integrated approach to project delivery. The study will involve a 45-60 minute interview which will be audio recorded using a digital voice recorder for the purpose of later transcribing and analysis only.

Please note that throughout the study you will remain anonymous with a pseudonym (false name) being used together with any potentially revealing information also being anonymised. You have the right to withdraw from the study at any stage and in such case your data will be deleted and not used. All raw data from the study, including the original audio recording of the interview, will be password protected and deleted at a later date following the successful completion of the assignment.

May I take this opportunity to thank you in advance for your valued input into my assignment and course.

Contact Details:

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Module Tutor: Professor Jason Underwood
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Figure 9. Participant Breif. Source: University of Salford.

8.3. Consent Form

University of Salford
MANCHESTER

<u>MSc. BIM & Digital Built Environments</u>

<u>Integrated BIM Projects Assignment Consent to Participate</u>

I have been asked to participate in an interview as part of an assignment, towards a MSc. in BIM & Digital Built Environments, concerned with exploring my views/perceptions/etc. on Building Information Modelling (BIM) and Lean in the context of an integrated approach to project delivery and give my free consent by signing this form.

- I have been informed about the study and why it is taking place.
- I have been informed why I have been asked to participate in the study.
- I understand that my participation in this study is completely voluntary and that I have the right to decline.
- I understand that I can withdraw from the study at any time and in such case my data will be destroyed and not included.
- I understand that I together with any potentially revealing information will remain anonymous in the study.
- I understand that the raw data, including the original audio recording of the interview, will be password protected during the study and destroyed at a later date following the student's successful completion of the assignment.

Printed Name ______________________

Signature ______________________

Date

Figure 10. Consent Form. Source: University of Salford.

8.4. Interview Questions/Prompts

1. Overall View on Digital Collaboration for Integrated BIM projects

• How would you define digital collaboration in your projects?
• How do digital tools like BIM, AI, and cloud platforms contribute to improving collaboration among stakeholders?

2. Challenges in Digital Collaboration to deliver integrated projects

• What challenges have you faced in implementing digital collaboration tools in your projects?
• If possible, provide examples of how resistance to adopting new tools has impacted collaboration or project outcomes.
• How do interoperability issues between different software platforms affect your workflows?

3. Enablers and Drivers of Digital Collaboration for integrated delivery

• Based on your experience, what does enable the successful digital collaboration on construction projects?
• How does the integration of technologies like digital twins, AI, AR, and VR impact project workflows and decision-making?
• Can you give an example of how leadership or training has enabled digital tool adoption within your organization?

4. Integrated Project Delivery (IPD)

• Have you led or been involved in projects that used IPD? If so, how did the practice affect collaboration and project outcomes?
• What do you think are the biggest advantages and disadvantages of the IPD model?
• How does the shared risk/ reward agreement in IPD affect how stakeholders behave?
• Do you have examples of how IPD fostered or hindered communication and decisionmaking?

5. Lean Construction
• How have you applied the principles of Lean Construction (or similar), such as waste reduction or continuous improvement, in your projects?
• What are some of the challenges faced while integrating Lean practices with digital tools like BIM?
• Give an example about how methods like the Last Planner System (LPS) or Target Value Design (TVD) influenced project efficiency, if any?
• What is, according to you, required to overcome cultural resistance to Lean practices in the industry?

6. Transparency and Communication

• How would you promote transparency and thereby engender trust among the different stakeholders whenever new collaborative tools or methods are introduced?
• In your view, what kind of strategies will help gain trust to overcome adversarial relationships in the industry?
• How has transparency or lack of it influenced decision-making and project outcomes in your view?

7. Role of Standards and Protocols

• How have standards such as ISO 19650 or Open BIM been influencing your way of managing project information?
• What challenges have you dealt with so far concerning these standards within the framework of training and resource allocation?
• How would you consider Open BIM in relation to collaboration or information exchange, in comparison to closed systems?

8. Organisational and Cultural Obstacles

• To what extent is implementing IPD, Lean and digital collaboration tools being interfered by traditional hierarchies or organizational structures?
• Which initiatives have you pursued with regards to mitigating cultural change in projects?
• Are there strategies or examples of what worked well to break down organizational silos?

9. Future Outlook and Recommendations

• What do you consider a future development or a trend that will shape digital collaboration, IPD, and Lean Construction in the AEC industry?

8.5. Interview Summary

Themes and Sub-themes	P1	P2
1. Integrated Project Delivery (IPD)	*"Early stakeholder involvement has been a game-changer for us. When we bring the owner, designers, and contractors together from the beginning, we can align on goals and avoid the usual blame game during conflicts."*	*"We don't use formal IPD contracts, but we try to implement its principles. For example, we emphasize early stakeholder involvement and shared decision-making, which improves alignment and reduces rework."*
• Collaborative Practices	*"Yeah, they have weekly meetings where they talk to the production leaders about what we are going to build next. They get feedback on what is important and address issues if needed."*	*"Without an IPD contract, our organizational structure relies on mutual trust rather than formalized processes. This works in small teams, but scaling it up is challenging because roles and responsibilities become less clear."*
• Organizational Structure	*"We don't have to go through 10 bosses to get an answer or something like that. So we have good communication. We make sure that we can all talk openly about issues and find quick solutions."*	*"We don't have a formal risk and reward system. Instead, collaboration is driven by mutual understanding and the need to meet client deadlines. While this can work, it lacks the accountability that a formal IPD contract could provide."*
• Risk and Reward	*"We also get a bonus if we finish the project early. So even if it's not officially defined as an IPD project, there are some close similarities that incentivize everyone to work toward common goals."*	*"The lack of an IPD contract means we miss out on some of the structured benefits, like shared goals and clear incentives. This leads to occasional misalignment between stakeholders, especially when unexpected risks arise."*
• Limitations	*"This is mostly about the contract. I don't think our project is based on IPD integrated project delivery, but collaboration happens despite that. Formal IPD agreements could strengthen consistency and accountability."*	
2. Lean Construction	*"I'm just making sure that they get all the information they need. The way we approach things is very lean because there are no roadblocks. If I have a problem, I go directly to that person, and we debate it and find a solution."*	*"Lean Construction has helped us eliminate redundancies in workflows, but its success depends heavily on how well the principles are understood by the team. We've integrated the Last Planner System to keep schedules predictable."*
• Workflow Efficiency	*"We regularly review workflows to identify areas of waste or redundancy, but success relies heavily on leadership supporting these iterative improvements."*	*"We use regular feedback loops to review processes, but the challenge is getting everyone to accept these iterative changes. It takes strong leadership to embed a culture of improvement."*
• Continuous improvement	*"Resistance to Lean practices is common, as stakeholders often hesitate to adapt workflows that feel unfamiliar, even if the benefits are clear."*	*"Adopting Lean is not always straightforward because some team members are resistant to change. They are more comfortable with the traditional 'we've always done it this way' mindset."*
• Challenges		

Table 5. Interview Summary

Themes and Sub-themes	P1	P2
3. Digital Collaboration • Tools and Platforms • Workflows • Open BIM • Learning environment • Challenges	*"We rely on open BIM standards like IFC and tools such as Revit and Tekla Structures to exchange data seamlessly. These tools help different disciplines collaborate effectively by ensuring everyone has access to the same model."* *"Sometimes it's not so easy to find the right tools that can provide what you need to empower your workflows while also being affordable."* *"The introduction of BIM kiosks and mobile devices on-site has allowed team members to retrieve the latest drawings or models immediately, eliminating delays caused by waiting for printed updates."* *"Different stakeholders come with different tools, and they are unlikely to change those tools. That's why Open BIM fits like a glove—it allows them to keep their tools, but they just have to learn how to use it effectively."* *"Unfortunately, many clients don't have BIM resources—they don't have BIM coordinators or BIM managers in their companies. You can hire a consultant, but they don't always have your best interests in mind. People still don't fully realize the importance of BIM roles or the need for competent individuals to adopt these new processes and ways of working."* *"The biggest challenge we face is with software updates—they sometimes disrupt access to models for hours, which can halt the entire workflow and frustrate teams."* *"Most software tools are not complete, so we use different tools to complement the process, which adds complexity. Additionally, most of these tools are very expensive, making it difficult for smaller firms to afford them."*	*"We use a combination of cloud-based tools and desktop software. Tools like Autodesk Construction Cloud are great for collaboration, but they come with limitations in data exchange when paired with older desktop solutions used by some teams."* *"Paperless workflows have significantly improved efficiency. With tablets on-site, workers can access up-to-date models instantly, but it requires rigorous training to make sure everyone uses these tools effectively."* *"Open BIM has been a game-changer for us. It allows us to work with international teams without worrying about proprietary software compatibility. However, not everyone understands how to maximize its potential."* *"We've implemented ongoing training programs for our team, but the shortage of qualified BIM professionals in the market makes it difficult to scale up operations, especially when dealing with complex projects."* *"The biggest challenge we face is ensuring interoperability across tools. Even with Open BIM standards, some tools don't integrate seamlessly, which forces us to resort to manual workarounds. Another challenge is keeping the tools updated."*
4. Drivers and Opportunities • Emerging Technologies • Leadership and Training • Cultural Shifts	*"Digital twins have revolutionized how we manage assets. By integrating real-time data from IoT devices, we can monitor the performance of a building even after project completion, which has been invaluable for maintenance."* *"We use a lot of AI, of course. Many tools have integrated AI, especially with tunneling, and I also use it in my own role for many, many things that I do."* *"Our leadership team actively supports digital transformation, which creates an environment where teams feel confident exploring new tools without fear of being penalized for mistakes."* *"We've had to focus heavily on building trust between teams, especially when introducing new collaborative tools. Without trust, transparency is impossible, and teams will always revert to old methods."*	*"Emerging technologies like AI and AR are becoming part of our workflow. AI is particularly helpful in automating clash detection, while AR provides immersive visualization for clients who might struggle to interpret 2D or 3D models."* *"The role of leadership in digital transformation is underestimated. Our leaders advocate for innovation and allo-cate time for training, which has been key to successful tool adoption across teams."* *"Changing the mindset of traditional project managers has been one of our biggest hurdles. Building trust and demonstrating the value of transparency is a slow process, but it's essential for true collaboration."*
5. Challenges and Barriers • Resistance to Change • Technological • Security	*"People are very conservative. It's not easy to introduce new platforms to people. The way I addressed challenges was to reduce the number of new tools for them, to be persistent, listen to their concerns, and empathize with their point of view."* *"Interoperability between systems remains a challenge despite using open standards. Data silos still exist when stakeholders rely on proprietary software."* *"The reliance on cloud platforms raises concerns about data security, especially when sensitive project information is shared across multiple stakeholders without clear protocols for access control."*	*"We've faced situations where senior managers refused to adopt new tools because they felt the learning curve was too steep. This resistance slows down the entire team's progress."* *"Despite using open standards like IFC, proprietary software still causes issues. It's frustrating when two tools don't integrate, forcing us to resort to manual workarounds."* *"Our projects don't require high security, but we try to apply access controls to ensure only authorized stakehold-ers can modify or view specific data. It's a basic precaution that adds an extra layer of accountability."*

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