Establishing the Core Requirements of Contractual Protocols for BIM Integration in Water Treatment Plant Development

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Abstract

The integration of Building Information Modelling (BIM) in water treatment plant (WTP) projects presents significant opportunities for improving design coordination, construction efficiency, and lifecycle asset management. However, the absence of robust contractual protocols tailored to BIM implementation often leads to ambiguity in roles, responsibilities, and data ownership, increasing the risk of disputes and inefficiencies. This study aims to establish the essential components of a contractual protocol specifically designed for BIM integration in WTP projects. A systematic literature review of ten key studies was conducted, covering BIM contractual frameworks, dispute resolution mechanisms, data management standards, and sector specific applications in the water industry. Findings reveal that effective contractual protocols require five core components: (1) clearly defined roles and responsibilities, (2) standardized workflows and data exchange formats, (3) intellectual property and data ownership clauses, (4) dispute resolution procedures linked to BIM deliverables, and (5) performance and compliance monitoring mechanisms. A proposed framework is presented to guide stakeholders in drafting BIM enabled contracts for WTP projects, reducing ambiguity and fostering collaborative project delivery.

Keywords: *BIM, Contractual Protocol, Water Treatment Plant, Roles and Responsibilities, Dispute Resolution, Data Ownership.*

1. Introduction

BIM adoption in the water sector is steadily increasing, driven by the need for improved design coordination, asset management, and operational efficiency. Water treatment plant projects, characterized by complex mechanical, electrical, and process engineering systems, stand to benefit significantly from BIM enabled collaboration. Despite its advantages, BIM integration introduces contractual challenges, including unclear allocation of responsibilities, intellectual property (IP) rights, and interoperability issues.

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Previous studies (e.g., Features and Conditions of BIM Contracts, 2020; Integrating BIM in Dispute Resolution, 2022) highlight the need for sector specific contractual frameworks. Yet, literature dedicated to WTP projects remains limited. This study seeks to fill that gap by identifying the core contractual requirements for BIM integration in WTP development.

2. Literature Review

Though the construction management field has investigated the creation of contractual frameworks for BIM enabled projects, insights specific to water treatment plant (WTP) projects are lacking. The literature indicates the presence of fundamental contractual concerns such as data ownership, liability distribution, interoperability, and mechanisms for resolving disputes which are all imperative for successful BIM utilization.

The study Features and Conditions of BIM Contracts [1] Names the key contracts necessary for BIM implementation which center around intellectual property rights, data and information security, responsibilities of liability, and the extent to which models may be used. These clauses are fundamental to guaranteeing that all legal and operational requirements of the stakeholders are met pertaining to BIM outputs and deliverables.

Integrating BIM in Construction Dispute Resolution [2] also looks at the inclusion of BIM in conflict resolution and the use of contracts in relation to evidence during disputes, advocating for specific clauses that allow BIM models to be used as evidence at arbitration or court. This demonstrates that BIM possesses the ability to enhance the efficacy of resolving disputes while eliminating the obscurity of project documentation. A preliminary framework for BIM enabled projects, proposed by researchers at Curtin University [3], emphasizes the explicit allocation of roles and responsibilities, integration of BIM Execution Plans (BEPs) into contracts, and adoption of standardized information management procedures. While general in scope, these recommendations can be adapted for the WTP sector, which often involves multi-disciplinary teams and high value mechanical and process engineering assets.

As far as contracted work on water infrastructural facilities is concerned, Scan to BIM: A Framework for Realizing Scan to BIM for Existing Water Facilities outlines the importance of Level of Detail (LOD) specifications as well as the standards of asset data within the contracts. Transfer of operational asset information is crucial for continuous upkeep of the system in Water Treatment Plants (WTP) facilities, in addition to ensuring the thorough capture and transfer of data streamlines ongoing maintenance and process optimization initiatives.

The application of BIM to a large wastewater treatment plant, as described in Intelligent Construction, Operation, and Maintenance of a Large Wastewater Treatment Plant, highlights the need for enduring maintenance workflows to be clearly defined in the contract, including intricate post-handover operational clauses. These obligations cover data maintenance and updates, system integration with facility management software, as well as maintenance reconcile obligations between plant operators and contractors.

Considering the interoperability of data, An IFC Schema Extension for BIM Based Description of Wastewater Treatment Plants offers extensions for Industry Foundation Classes (IFC) regarding wastewater treatment plants processes and assets. Such contracts must be complemented with specific provisions ensuring compliance with industry standards to achieve enduring interoperability across software platforms and among project participants. Sector level insights are provided by the *BIM Adoption Case Study Report Review of Benefits, Challenges, and Lessons for the Water Industry* [7], which documents empirical issues faced by water utilities, including vendor lock in for data formats and unclear responsibilities for data verification. These challenges reinforce the need for clear contractual allocation of data provision and validation duties.

In legal scholarship, an example is Contractual Challenges for BIM based Construction Projects [8], which examines 28 kinds of legal and contractual risks, covering issues such as intellectual property, professional liability, insurance coverage, and risk allocation. These categories may be processed as a checklist while servicing WTP specific BIM protocols.

Also, Critical Success Factors and a Contractual Framework for Construction Projects [9] outlines factors and conditions which enhance the contracts execution and include: well defined communication channels, clearly defined and quantifiable performance benchmarks, and active participation of the defined stakeholders in the drafting of the contract. These factors, when applied in the context of WTP BIM enabled projects, serve to enhance transparency as well as mutual accountability.

Lastly, professional issues are dealt with in Practitioners' Concerns about Their Liability toward BIM [10], an article which examines liability concerns held by engineers and contractors with regard to BIM outputs. The article has also recommended that there be clauses which prescribe liability caps, insurance thresholds, and warranties obligations BIM defined.

The integration of the above is a possible starting point for creating a WTP specific contractual structure for BIM integration.

3. Methodology

This study adopts a qualitative research design combining systematic literature review (SLR) and thematic analysis to establish the core requirements of contractual protocols for BIM integration in water treatment plant (WTP) development. The

methodological approach consists of three main stages: literature identification, thematic synthesis, and framework formulation.

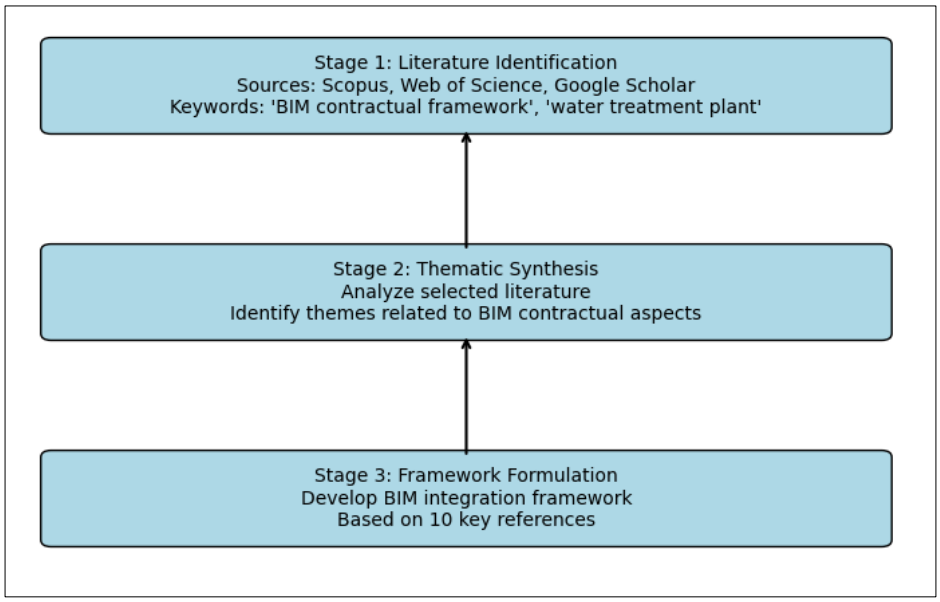

Figure 1. Methodological Framework for Identifying Contractual Requirements in BIM Integrated Water Treatment Projects

Figure 1. illustrates the three-stage methodological framework adopted in this study. The process begins with **literature identification**, where relevant sources are retrieved from major academic databases using targeted keywords. This is followed by **thematic synthesis**, in which key themes related to BIM contractual protocols are extracted and categorized. Finally, the study culminates in **framework formulation**, where the synthesized insights are structured into a practical model applicable to water treatment plant (WTP) development. This flowchart ensures a systematic and transparent approach to deriving contractual requirements for BIM integration in infrastructure projects.

3.1 Literature Identification

Relevant literature was collected from leading academic databases, including Scopus, Web of Science, and Google Scholar, using keywords such as *"BIM contractual framework"*, *"water treatment plant"*, *"BIM integration"*, *"BIM dispute resolution"*, and *"contractual challenges in BIM"*. The inclusion criteria focused on peer reviewed journal articles, conference proceedings, and technical reports published between 2010 and 2024. This timeframe captures the most recent developments in BIM contractual practices, especially those applicable to the water sector. The 10 key references reviewed in Section 2 [1–10] were selected for their

direct relevance to contractual aspects of BIM and potential adaptability to WTP contexts.

3.2 Thematic Synthesis

The content of each selected study was examined to extract contractual considerations relevant to BIM integration. This involved coding each reference for recurring themes, such as:

i. **Roles and responsibilities allocation** (e.g., BIM Execution Plans, lead model manager)
ii. **Intellectual property and data ownership** (e.g., model rights, licensing terms)
iii. **Interoperability and technical standards** (e.g., IFC schema requirements, software compatibility)
iv. **Liability and risk allocation** (e.g., professional liability, insurance, warranties)
v. **Dispute resolution mechanisms** (e.g., arbitration, mediation, evidentiary use of BIM models)
vi. **Post-handover obligations** (e.g., FM integration, operational data updates)

The thematic coding was guided by the framework proposed in [8,9] and adapted to the technical and operational context of WTP projects as illustrated in [4–6].

3.3 Framework Formulation

The synthesized themes were structured into a proposed conceptual framework for contractual protocols in BIM enabled WTP projects. The framework outlines the minimum contractual components required to ensure legal clarity, operational efficiency, and BIM process alignment. It is designed to be adaptable to different project delivery models (e.g., Design Build, EPC, PPP) while ensuring compliance with industry standards such as ISO 19650 for information management.

The methodology is primarily qualitative and interpretive, aimed at integrating theoretical insights with practical considerations. While empirical validation through industry surveys or case studies is beyond the scope of this paper, the proposed framework is intended as a foundation for future applied research and pilot implementation.

4. Findings and Discussion

The thematic analysis of the reviewed literature [1–10] produced six core contractual requirement categories essential for BIM integration in water treatment plant (WTP) development. These categories reflect a synthesis of both general BIM

contractual considerations and sector specific operational needs identified in WTP related studies.

4.1 Core Contractual Requirements

The results indicate that a well-structured contractual protocol for BIM enabled WTP projects should address the six key areas summarized in Table 1. These areas are interdependent, with each contributing to a cohesive and enforceable agreement that supports both technical performance and legal compliance.

Table 1. Core Contractual Requirements for BIM Integration in WTP Projects

No.	Contractual Requirement Area	Description	Example Contractual Provisions
1	Roles and Responsibilities	Clear allocation of BIM related duties among stakeholders, including model authoring, coordination, and review responsibilities.	Appointment of a BIM Manager; BIM Execution Plan incorporated into contract.
2	Intellectual Property & Data Ownership	Definition of ownership rights for BIM models and datasets, including licensing terms for reuse and sharing.	Clause specifying model ownership remains with client; design team retains authorship rights.
3	Interoperability & Technical Standards	Mandating data formats, software compatibility, and adherence to industry standards for seamless information exchange.	IFC schema compliance; LOD specifications for asset data.
4	Liability & Risk Allocation	Clear provisions for professional liability, errors and omissions, and insurance requirements related to BIM deliverables.	Limitation of liability clauses; professional indemnity insurance coverage.
5	Dispute Resolution Mechanisms	Procedures for resolving disagreements, including use of BIM models as evidentiary records.	Arbitration clauses recognizing BIM models as admissible evidence.
6	Post-Handover Obligations	Requirements for updating as built BIM models and integrating with facility management (FM) systems.	Clauses mandating data updates for operational assets for 2 years post-handover.

This table outlines the key contractual domains that must be addressed to ensure the successful implementation of Building Information Modeling (BIM) in Water Treatment Plant (WTP) projects. Each domain represents a critical legal or operational consideration that affects collaboration, data integrity, and long-term asset performance.

To ensure effective BIM implementation in water treatment plant (WTP) projects, this study identifies six core contractual requirement areas that must be addressed within project agreements. These include the clear delineation of roles and responsibilities among stakeholders, particularly regarding model authoring, coordination, and review; the definition of intellectual property rights and data ownership to safeguard model integrity and usage; and the specification of interoperability standards to facilitate seamless data exchange across platforms. Additionally, provisions for liability and risk allocation are essential to manage professional accountability and insurance coverage, while dispute resolution mechanisms such as recognizing BIM models as admissible evidence support fair and efficient conflict management. Finally, post-handover obligations must be contractually defined to ensure the timely updating of as built models and their integration into facility management systems. Collectively, these requirements establish a foundational legal framework that supports digital collaboration, reduces ambiguity, and enhances lifecycle asset performance in BIM enabled infrastructure projects.

4.2 Discussion

The analysis reveals that while some contractual requirements are consistent with those in conventional construction contracts, others are uniquely critical to BIM enabled WTP projects. For instance, *interoperability and technical standards* (Requirement 3) are especially important due to the diverse range of software and instrumentation systems used in WTP operations [4,6]. Without clear contractual mandates for standardized data formats (e.g., IFC, COBie), long term data usability and integration with supervisory control and data acquisition (SCADA) systems may be compromised.

Similarly, *post-handover obligations* (Requirement 6) emerged as a distinct need in the WTP sector, where operational continuity and regulatory compliance depend on accurate, up to date digital asset records [5]. This differs from typical building projects where the operational handover may be less data intensive.

The contractual clarity on *roles and responsibilities* (Requirement 1) and *liability allocation* (Requirement 4) directly addresses common causes of disputes in BIM projects [8,10]. These provisions ensure that design errors, data omissions, or coordination failures are traceable to the responsible party, reducing ambiguity and supporting more efficient resolution when disputes arise.

4.3 Proposed Conceptual Framework

The proposed conceptual framework (Figure 2) integrates six key contractual requirement areas into a process model specifically designed for BIM integration in WTP projects. The framework is organized into three phases: Pre-Contract Planning, Project Delivery, and Post-Handover. Each phase incorporates pertinent contractual elements to maintain continuous alignment between legal agreements and BIM enabled workflows.

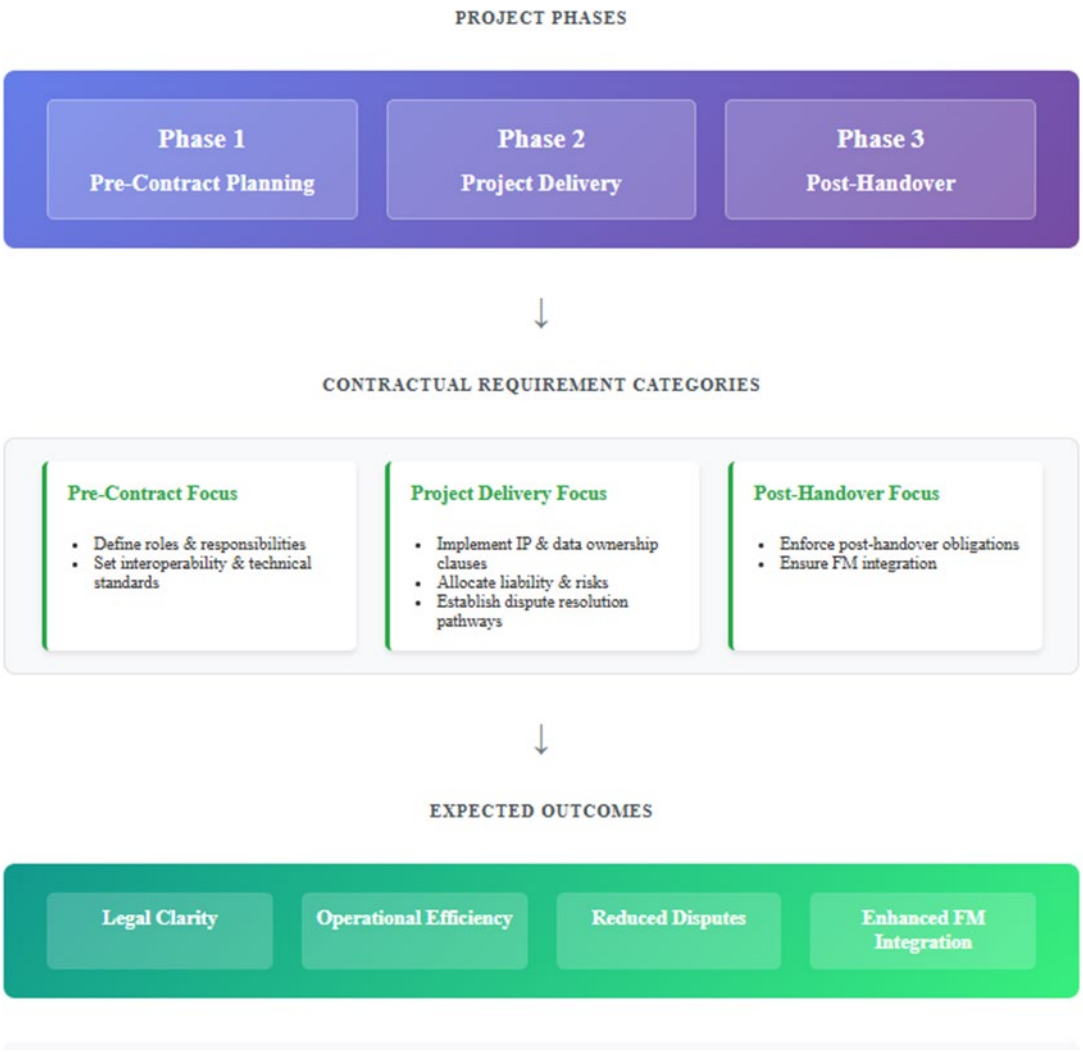

Figure 2. Conceptual Framework for Contractual Protocols in BIM Enabled WTP Projects

The proposed framework, illustrated in Figure 2, adopts a three-phase structure: Pre-Contract Planning, Project Delivery, and Post-Handover. This structure provides comprehensive contractual support for BIM integration in water treatment plant (WTP) projects. Each phase includes specific contractual requirements designed to address potential risks and enhance project outcomes.

Phase 1: Pre-Contract Planning

This initial phase sets the foundation for effective BIM implementation by clearly defining the roles and responsibilities of all project stakeholders, including designers, contractors, consultants, and facility managers. Equally important is the establishment of interoperability and technical standards, such as adherence to the Industry Foundation Classes (IFC) schema and agreed Levels of Development (LOD) for project deliverables. By embedding these requirements in the tender and procurement documentation, project teams minimize ambiguity, ensuring that all parties commit to consistent digital practices from the outset.

Phase 2: Project Delivery

During the execution phase, the contractual framework must include specific clauses addressing intellectual property (IP) rights and data ownership to safeguard the proprietary interests of contributors and clarify usage rights for the BIM model. Liability allocation provisions are essential to delineate responsibility for errors, delays, or non-compliance with BIM standards. Additionally, formal dispute resolution pathways such as mediation or arbitration mechanisms should be pre agreed to handle any BIM related conflicts efficiently. These measures collectively enhance legal certainty, reduce the potential for litigation, and maintain collaborative project momentum.

Phase 3: Post-Handover

The final phase focuses on sustaining the value of the BIM deliverables beyond project completion. Contracts should stipulate post-handover obligations, including the delivery of fully verified as built BIM models in an agreed format suitable for facility management (FM) applications. Integration with FM systems ensures that the digital asset supports ongoing operation, maintenance, and future upgrades, ultimately extending the lifecycle value of the infrastructure. Training provisions for FM staff further strengthen the handover process, ensuring that operational teams can fully leverage the BIM model's capabilities.

Expected Outcomes

When executed effectively, a phased contractual approach to Building Information Modeling (BIM) implementation offers significant benefits for water treatment plant (WTP) projects. By aligning contractual provisions with the distinct phases of the project lifecycle feasibility, design, construction, and operation, this approach provides both immediate and long-term advantages that enhance efficient project delivery and sustainable asset management.

1. **Legal clarity**. The phased protocol, which explicitly defines rights, responsibilities, and liabilities at each stage of the project. Clear allocation of data ownership, intellectual property rights, and responsibilities for model development reduces ambiguity and minimizes the potential for disputes. This clarity is especially important in WTP projects, where multiple

stakeholders including civil, mechanical, and electrical disciplines must collaborate within a shared digital environment.

2. **Operational Efficiency**. Embedding BIM deliverables into contractual milestones through a phased approach enhances coordination across design, construction, and facilities management (FM) activities. This integration minimizes duplicated efforts, facilitates clash detection and constructability reviews, and improves procurement planning. For water treatment plant (WTP) projects, it results in more predictable project outcomes and greater efficiency during the transition from construction to operation.

3. **Reduced Disputes** result from the inclusion of standardized data exchange protocols, review schedules, and pre agreed dispute resolution mechanisms, which provide a structured foundation for collaboration. By addressing potential conflict areas in advance, the phased contractual framework minimizes the occurrence of claims and disputes during project execution. In water treatment plant (WTP) projects, this proactive structure is especially valuable due to the high level of interdisciplinary interaction and technical complexity involved.

4. **Enhanced FM integration** is a key advantage of the phased contractual approach, as it extends BIM obligations beyond construction into the operational phase. This ensures that facility managers receive a comprehensive and accurate as built digital model, which can be utilized for predictive maintenance, asset tracking, and lifecycle cost management. Consequently, the digital model remains a valuable tool throughout the asset's lifecycle, supporting the long-term sustainability of WTP infrastructure.

Overall, this structured alignment of contractual requirements with project phases not only facilitates smoother BIM adoption in WTP projects but also ensures that the digital asset retains its value throughout the entire lifecycle of the infrastructure.

4.1 Core Requirement Components

1. **Roles & Responsibilities** – Clear definition for client, consultant, contractor, and operator, including BIM Manager and Data Custodian roles.
2. **Workflows & Data Exchange** – Agreed standards (IFC, ISO 19650) and level of development (LOD) specifications for WTP design and O&M stages.
3. **IP & Data Ownership Clauses** – Explicit terms for model ownership, licensing, and usage post-handover.
4. **Dispute Resolution Integration** – BIM models and CDE logs as admissible evidence in claims and arbitration.
5. **Performance & Compliance Monitoring** – KPIs linked to BIM execution plan (BEP) and regulatory compliance (water quality, environmental standards).

4.2 Proposed Contractual Framework

The proposed contractual framework for BIM integration in water treatment plant (WTP) development is structured across three distinct phases to ensure clarity of roles, responsibilities, and deliverables. This phased approach aims to reduce contractual ambiguity, enhance data management, and facilitate smooth project execution.

4.2.1 Pre contract phase

During the pre-contract phase, BIM requirements should be explicitly incorporated into the tender documentation. This includes defining the Level of Development (LOD) for each discipline, specifying interoperability standards (e.g., IFC compliance), and identifying the software platforms to be used. Tenderers should be required to submit preliminary BIM Execution Plans (BEP) outlining their proposed workflows, data exchange methods, and quality control measures. Early inclusion of these requirements ensures that all bidding parties understand and commit to the project's digital collaboration expectations from the outset.

4.2.2 Contract phase

In the contract phase, the agreed BIM Execution Plan (BEP) and Data Management Protocols must be embedded as contractual appendices. These documents should define the Common Data Environment (CDE) governance rules, data ownership and intellectual property (IP) rights, model review procedures, and dispute resolution mechanisms related to digital deliverables. Embedding these protocols within the contract transforms them from aspirational guidelines into enforceable obligations, reducing the risk of disputes and misinterpretations.

4.2.3 post contract phase

The post contract phase focuses on formalizing the handover of asset information and integrating it into facility management systems. The contractual provisions should specify the format, completeness, and verification process for the as built BIM models, ensuring alignment with operational requirements. Additionally, the framework should address training for facility management teams, ensuring they can effectively use the BIM model for maintenance, lifecycle management, and future upgrades.

This structured, three phase contractual framework ensures that BIM implementation in WTP projects is supported by clear, enforceable agreements that align with both project delivery and long-term asset management objectives.

5. Conclusion

This study identified and synthesized the essential contractual requirements for effective Building Information Modeling (BIM) integration in water treatment plant (WTP) development. Through a thematic analysis of ten key references, six interrelated areas of contractual requirements were established: (1) roles and responsibilities, (2) intellectual property and data ownership, (3) interoperability and technical standards, (4) liability and risk allocation, (5) dispute resolution mechanisms, and (6) post-handover obligations.

The findings highlight that, while many BIM contractual considerations are consistent across construction sectors, WTP projects require greater technical specificity, particularly regarding interoperability standards, asset data requirements, and operational handover procedures. These elements are critical due to the sector's reliance on complex mechanical, electrical, and process systems, as well as regulatory compliance obligations that extend well beyond project completion.

The proposed conceptual framework provides a structured approach to integrating these contractual elements throughout the project lifecycle from pre contract planning to post-handover ensuring alignment between legal provisions and BIM enabled workflows. By adopting this framework, stakeholders can achieve greater legal clarity, enhance operational efficiency, and reduce the likelihood of disputes.

Future research should prioritize the empirical validation of the framework through case studies or pilot implementations in real world WTP projects. This approach would facilitate the refinement of contractual clauses and the development of sector specific BIM execution standards, ultimately promoting more sustainable and collaborative project delivery models.

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Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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