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RESEARCH ARTICLE

Client-Driven Level 2 BIM Implementation: A Case Study from the UAE

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Abstract:

Background:

Implementation of Building Information Modelling (BIM) has proven to deliver major performance improvements in Program efficiency, design quality, constructability, waste reduction, environmental performance, and capital & operational cost management of built environment projects. Yet BIM implementation in low BIM maturity markets, such as the UAE, is limited to technology applications which fail to deliver the full potential of BIM benefits to client originations.

Objective:

The purpose of this paper is to investigate BIM implementation from a client's perspective and to present a case study that exhibits a level 2 BIM implementation process in a traditional procurement environment.

Methods:

The study has used a case study approach combined with a literature review. A critical appraisal of relevant literature is presented to highlight key issues hindering BIM implementation for client organizations, especially in developing BIM markets, such as the UAE. The research is collected using an action research approach within a case study, including project document audit, participation in project collaboration meetings and extensive communication with the project stakeholders. The case study is presented in a practice-oriented research format describing the project details, procurement approach, BIM development & management process and benefits achieved for the project client.

Results:

The paper presents a structured approach to strategically introduce BIM within a low BIM maturity market, creating partnering relationships, empower the supply chain partners and achieving significant BIM benefits with minimum disruption to existing work practices. The paper highlights that although BIM requires a step-change in the work practices of the construction industry, yet it is possible to successfully implement BIM with traditional procurement settings, which may be a critical feature in a certain market or a client requirement.

Conclusion:

There is a need for case study based, practice-oriented research work within the domain of BIM implementation. Construction clients in low maturity BIM markets are concerned about the perceived benefits of BIM and its practical implementation within existing business practices, which is addressed in this paper. Overall, the findings of this study are useful for construction industry clients and academia in redefining the existing work practices to incorporate BIM-enabled processes and applications.

Keywords: BIM, UAE, Construction, Case study, Project management, Integrated.

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1. INTRODUCTION

The construction sector is the 5th largest sector in the United Arab Emirates (UAE). Projects costing over 45 billion USD were awarded in 2017 [1] and the UAE construction industry previously completed approximately 70 billion USD worth of construction projects between 2015 and 2016, which were mostly residential and commercial high-rise building

projects. At present, several mega infrastructure projects that are worth over 55 billion USD are underway in the UAE, including the construction of metro lines, the Expo 2020, airport extensions, etc. However, construction clients in the UAE constantly face poor project delivery, not only in terms of time and cost but also in the management of built assets. Researchers have reported that about 50% of the UAE projects were analyzed with time and cost overruns because of approval delays, delays in client decision-making, and poor initial planning [2, 3]. Another study [4] found that the Dubai metro

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was the third most troublesome project, as it suffered from a 5-year delay and an 85% increase in the estimated budget, which were mainly due to a substantial number of disputes resulting from design and scope changes. The 29 stations across the red line and 20 stations across the green line were initially planned to be completed by September 2009 and March 2010, respectively, but due to some major disputes, only 10 stations were completed across the red line by September 2009, and the entire project was eventually completed in March 2014, so the project was delayed by 5 years [2, 4]. Other reports also showed that 70% of the projects in the UAE are subjected to time overruns due to problems in monetary resources, contractual differences, approvals, and licensing [5, 6]. Therefore, improving the performance of construction projects is a vexing issue for construction clients in the UAE, and a slight improvement in this sector can bring substantial savings in capital expenditures.

The emergence of the digital era and the call to adopt Building Information Modeling (BIM) and smart technologies have been heralded as enablers to improve the performance of an asset over its lifecycle. The BIM is a technology-driven integrated digital process, and it uses intelligent geometric and data models that can provide coordinated, reliable information about a project throughout its entire lifecycle [7]. BIM implementation represents a major change in the tools and processes used to design, construct, and manage buildings and infrastructure. When properly implemented, it delivers major performance improvements in program efficiency, design quality, constructability, waste reduction, environmental performance, and capital and operational cost management [8 - 10]. Owing to the acclaimed benefits of BIM, public client organizations, as well as private clients, have mandated the use of BIM to improve construction projects' performances. For example, the UK Government has set up a BIM Task Group and agreed on a BIM strategy that requires the use of collaborative 3D BIM to reduce the capital expenditure on all public sector projects by 20% starting from 2016 [11].

Also, a government-driven BIM mandate has already been enforced in several other countries, such as the US, Norway, Finland, HK, South Korea, Singapore, and Australia [12, 13]. Similarly, the Dubai Municipality has mandated the use of the BIM for significant built environment projects (*i.e.*, higher than 20 stories or for areas larger than 200k SQFT) [14] and it is followed by several other governments & commercial clients in the UAE, such as the RTA (Road and Transport Authority) and the DOT (Department of Transport).

However, BIM implementation in developing BIM markets, such as the UAE, is mainly driven by the technological advantages of BIM, where a client is rarely engaged in the BIM development process due to non-collaborative practices and reliance on traditional procurement systems. Moreover, the BIM implementation has introduced a new line of challenges for client organizations in redefining existing work practices to incorporate BIM-enabled processes. For example, most construction projects in the UAE are delivered using traditional procurement (*i.e.*, design-bid-build) because of the risk strategies and investment policies of construction clients who typically prefer the selection of lowest-bid contractors. This raises the questions "what are the

challenges for client organizations in implementing BIM in a low BIM maturity market?" and "how does a client foster early project collaboration and can benefit from various BIM applications on a project within a traditional procurement environment?"

BIM implementation can be divided into several tiers of maturity, namely, levels 1, 2, and 3, where a BIM maturity level refers to the technology-enabled processes and collaborative BIM applications in a project. Level 2 BIM is acclaimed to bring most of the associated BIM benefits while transiting from existing practices to BIM [15]. This paper presents findings of a study that has investigated BIM implementation from a client's perspective using a literature review and case study approach. A critical appraisal of relevant literature is presented to highlight key issues hindering BIM implementation for client organizations, especially in developing BIM markets, such as the UAE. A detailed case study is presented where a client-driven BIM mandate was used to implement level 2 BIM, including project details, procurement approach, BIM development & management process, and benefits achieved for the project client. The case study presents a structured approach to strategically introducing BIM implementation within a low BIM maturity market, creating partnering relationships, empowering supply chain partners, and achieving significant BIM benefits with minimum disruption to existing work practices.

2. LITERATURE REVIEW

2.1. Understanding Level 2 BIM

The effectiveness of working with Building Information Models depends on the degree of sophistication involved in the development of model contents and the way it is coordinated and managed across the life cycle of a project, which is called "BIM maturity levels" [16]. The BIM maturity levels and their relationship with collaborative working, data processing, and underlying technologies are described in Fig. (1).

The BIM maturity level determines the degree of efficiency in implementing the technology and process in regard to collaborating building information in a project environment. Level zero BIM maturity reflects unmanaged CAD in 2D, which is represented and exchanged in paper documents (including electronic documents). The collaboration at level zero is minimum, as information is exchanged using ad-hoc exchange methods that offer very little or no chance of information integration to support collaborative working. Level 1 denotes a managed CAD environment that uses 2D and 3D representations of building information. The information content at level 1 is created using standardized approaches to data structures (CAD standards), and it is stored in standard formats that can be exchanged among different CAD applications. Also, Level 1 replaces the ad-hoc information exchange mechanisms with the introduction of a Common Data Environment (CDE), which is used to share and exchange CAD files between various project participants. However, traditional CAD information still consists of drawings and documents without any embedded intelligence, which can offer opportunities for information integration by unlocking the potential of collaborative working.

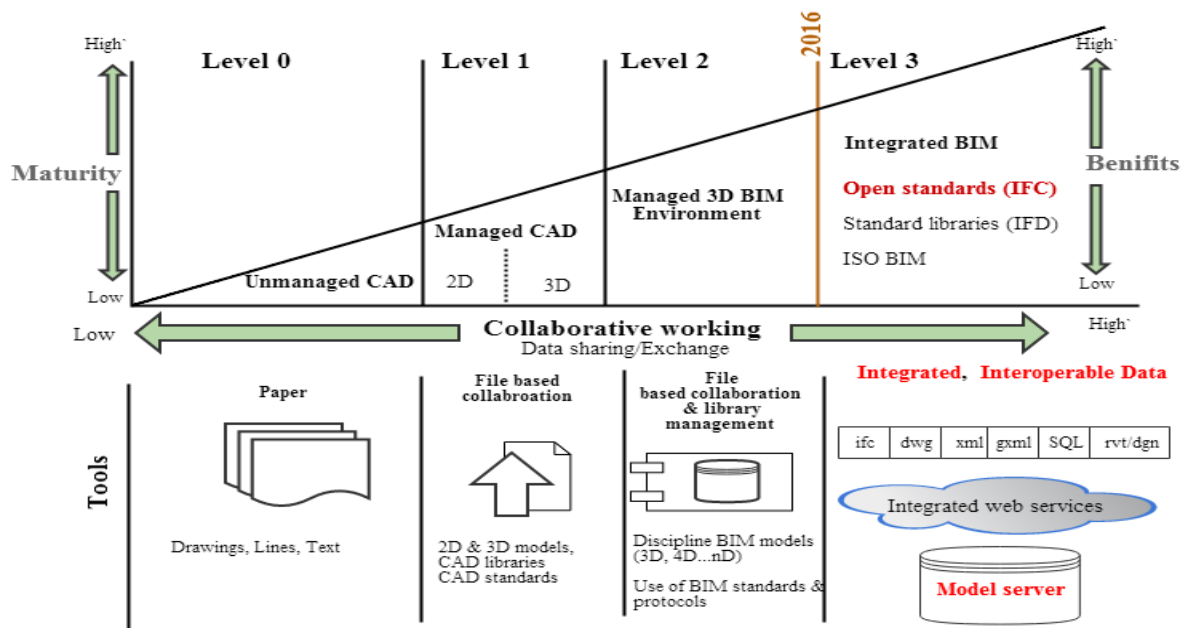


Fig. (1). BIM implementation levels (modified from the Bew–Richard BIM maturity model).

Level 2 denotes a managed BIM environment that contains intelligent BIM models held in separate disciplines (discipline models), shared and coordinated using a structured approach on a CDE, and integrated using proprietary or bespoke middleware software for design (e.g., architectural structural, etc.), analysis (e.g., energy analysis, clash detection, etc.), project management (e.g., 4D, 5D), and maintenance purposes (e.g., COBie). Level 2 BIM is most desired by client organizations, as it can be achieved without fundamental changes to business practices, and it can also provide significant improvements in project delivery. The UK Government targeted a 20% reduction in the expenses of construction projects and required level 2 BIM for all public sector projects (with all the project and asset information, documentation, and electronic data) starting from 2016. Level 3 BIM denotes fully integrated and collaborative BIM, which is enabled by web services to facilitate collaborative building information using open standards (e.g., Industry Foundation Class (IFC)) without interoperability issues. It also extends the use of BIM applications toward the lifecycle management of building projects.

BIM Level 2 is designed with the intention of achieving a small step-change from the current standards and tools deployed in the construction industry. Moreover, although BIM Level 2 adoption has proven to be successful, BIM still requires a high level of collaborative working among the AEC disciplines—beyond traditional work boundaries with restricted contractual relationships—to achieve high-performing, low-cost built environments. Supporting this idea [17], investigated level 2 BIM collaborative workflows and concluded that the existing original practices must be transformed to successfully implement level 2 BIM. Another research [18] highlighted that contract provisions must be

amended to support BIM implementation in projects. Within this context, the early project stages are critical for establishing comprehensive BIM development and implementation strategies that can facilitate integration and collaboration among team members through an entire project. However, traditional procurement forms do not support the early involvement of key project stakeholders, such as the involvement of a contractor in the design stage. Several authors have stressed that the construction industry is slow in the adoption of BIM, as there are no significant changes in traditional business models for facilitating the use of BIM and its associated processes [10]. However, most construction projects are delivered using traditional procurement (i.e., design–bid–build) because of the risk strategies and investment policies of construction clients who typically prefer the selection of lowest-bid contractors. Therefore, one of the main issues for construction clients in implementing BIM is the use of innovative strategies, which can deliver the best value for project owners with minimum disruption to existing work practices.

2.2. BIM Implementation Challenges for Client Organizations

In spite of the client-enforced BIM requirements and Government Support, the BIM adoption in the UAE is limited to BIM technology applications with no focus on essential process improvements and collaborative work practices, which are fundamental for delivering client-centric BIM benefits to the built environment projects. For example, in the current BIM development process, a consultant’s BIM model is hardly ever transferred to a contractor to integrate the construction information about the installed products, which enhances a BIM model, for it to be used by the owner for operation and

maintenance tasks. On the contrary, the BIM development process is rebooted with changes in the responsibility at a tender stage, or it is outsourced overseas to create a new BIM model for the construction stage and hand over, which is even worse. This non-collaborative practice eradicates most of the intelligence factors in BIM models, making them less valuable to clients for any future use. Because of the traditional procurement boundaries, consultants and contractors are usually reluctant to share the details of these failures due to a perceived risk of reputation damage and to avoid the loss of any future business opportunities. Similar issues were pointed out by several research studies. For example, a study [19] highlighted the fact that the BIM awareness in the UAE is a result of the extensive and aggressive campaigns of software vendors, which are mainly carried out to increase product sales. Therefore, the point of view of vendors regarding the BIM benefits and claims have become apparent in the region. This dilemma has resulted in “lack of support from the top management to accept the change initiative to implement BIM,” as decision-makers are not aware of the BIM potential beyond its software applications. [20] analyzed the BIM implementation in the UAE and reported that the usage of popular procurement methods (*i.e.*, design–bid–build) prevents participants from getting involved in the design stage, resulting in a lack of cooperation and information exchanges and thus in low coordination levels, which limits the use of the BIM in construction projects.

Another study [21] conducted to investigate the BIM implementation in the UAE found that the lack of experience and knowledge, lack of awareness of BIM benefits, lack of client demand, and resistance to change traditional practices and investment expenses are among the key factors that hinder the BIM implementation in the UAE. Another survey [22] reported that only 20% of the AEC organizations in the Middle East use BIM or are in the process of adopting it, and even they still regard BIM as merely an advanced AutoCAD tool. These authors stressed on raising awareness regarding the BIM benefits so that all construction stakeholders can benefit from the wider applications of BIM. The following subsections summarize the key challenges facing effective BIM implementation in low BIM maturity markets.

2.2.1. BIM Standards and Protocols

Several studies have shown that one of the key obstacles in the widespread of the BIM in the industry is the lack of client demand, especially in developing countries, such as the UAE [23, 24]. This situation has been addressed by several government-led initiatives in other countries by introducing well-defined BIM requirements to the provision of financial initiatives and by applying the mandated use of BIM in public sector projects, such as in the UK [25]. The UK’s approach has been acclaimed for its well-considered integration of the policy across many industries and government stakeholders, and it was supported by several guidelines, standards, and tools to achieve the required BIM mandate [17, 18]. For example, the UK BIM task force developed PAS1192-2, PAS1192-3, BS1192-4, and PAS1192-5 frameworks that specifically address several aspects of the BIM development, management, and collaborative working so as to support the required BIM

mandate. The development of the NBS(National Building Specifications) BIM toolkit is another example of the Government Funded, Industry-led research efforts for supporting the implementation of Level 2 BIM in the UK. However, it is argued that this life cycle thinking and the inclusion of the information requirements of client perspectives (as in the case of the UK Government being the largest construction client in the country) may prove to be the key success factor for the widespread adoption of the BIM in the future [25]. In the UAE, there are no specific guidelines and standards for supporting the BIM implementation in the region. Also, the UAE’s construction industry uses BIM standards and protocols that were previously developed in the UK or in the USA on an ad-hoc basis, which often leads to confusion and confrontation among supply chain partners.

2.2.2. Low BIM Maturity in a Market

A key issue for client organizations regarding the implementation of the BIM in the region is identifying the BIM maturity of the supply chain partners and pre-qualifying them accordingly. The BIM maturity determines the degree of efficiency in implementing the technology and the process of collaborating building information in project environments. From the perspective of a client, “minimum BIM qualification” can be translated to “minimum capability to use BIM.” Several proposed frameworks and guidelines have been reported to measure projects and the organizational BIM maturity of supply chains to benchmark the BIM performance [26 - 28]. A BIM maturity and performance benchmarking framework allows organizations to lay a foundation for a formal assessment of their suppliers and to prequalify them based on their BIM capability. This can also be employed by government authorities, regulatory bodies, and large clients so that they can assess their own performance and adopt a continuous improvement approach to move to higher maturity levels. There is also a need for specialized BIM consultants to streamline the entire BIM process while ensuring that the BIM benefits are transferred to the project owner. Supply chains only provide what they are asked for; therefore, clients need independent BIM consultants or in-house BIM experts for the relevant quality assurance and control of the entire BIM implementation process to ensure that it meets client requirements as agreed in project charters.

2.2.3. Procurement and Legal Issues

To achieve high-performing, low-cost built environments, the BIM adoption requires a higher level of collaborative work among construction disciplines beyond the traditional work boundaries and restricted contractual relationships. Also, early project stages are critical for establishing comprehensive BIM development and implementation strategies that can facilitate integration and collaboration among team members through the entire period of a project [10]. However, traditional procurement forms do not support the early involvement of key project stakeholders, such as the involvement of a contractor in the design stage. For example, construction clients in the UAE are used to working with the traditional procurement approach (*i.e.*, design–bid–build) because of their own risk strategies and investment policies, which typically favor the selection of the

lowest-bid contractors. Therefore, one of the main issues that face construction clients in the UAE is the movement from a lowest-bid procurement process to an alternative delivery method that can deliver the best value for project owners by using innovative ideas, such as the BIM, with minimum disruption to existing work practices [20]. Another key obstacle in using the BIM for clients is that the BIM application raises critical contractual issues related to project responsibilities, contractual indemnities, risks, data ownership, and copyright issues. These issues are not addressed in the legal frameworks and contracts used in the region, so the UAE industry clients must rely on the developed legal frameworks in other countries (the Consensus-docs 301 BIM addendum or AIA's E203, G201).

2.2.4. Technology Barriers

The BIM implementation introduced several technology-related issues resulting from the object-oriented nature of the BIM and the available software applications for creating, managing, and maintaining these models. Supply chain partners are usually trained and experienced in a certain line of BIM software applications (e.g., Autodesk, Bentley, ArchiCAD), which leads to interoperability issues during the BIM development and coordination stages. Interoperability is the ability to manage and communicate electronic products and project data, such as the design, construction, maintenance, and business process systems, between collaborating firms and within individual companies [29]. To make the information available to project stakeholders, the utilized software applications need to have accurate data exchange facilities without depending on proprietary data formats, such as by using the IFC [30]. The lack of experienced supply chain partners in using interoperable data in BIM collaboration operations imposes serious disruptions for project teams and often restricts the choices of supply chain partners for clients based on their technical expertise in using BIM tools.

2.2.5. Risk Sharing

The disruptive nature of BIM processes and deliverables adds additional risks to project stakeholders at all stages of a project. A unique characteristic of a BIM project is that a shared model can contain data information that is not "signed off" by the content author [25]. Thus, project participants can assume that some models, which belong to other stakeholders, are accurate, which results in a risk of using inaccurate data. Traditionally, the currencies of exchanging information in the AEC industry are drawings and specifications, which can be easily authorized and protected by intellectual property rights. In the case of BIM models, they can contain a tremendous amount of electronic information, which can have significant commercial values to its authors and thus can be distributed and reused unethically. For project owners, the final BIM model should have all the required as-built information for facility management, so it should be governed by an intellectual property right contact between the project owner, design consultant, and contractor [31, 32].

In summary, the key challenges facing client organizations in the BIM implementation within low BIM maturity markets

are the (1) inexperienced supply chain partners, (2) traditional procurement and legal frameworks, (3) lack of technical expertise, and (4) technology barriers.

3. CLIENT-LED BIM IMPLEMENTATION: A CASE STUDY

This paper presents a case study from the UAE in which a semi-government client organization mandated the use of BIM in the project as a strategic decision and employed a BIM consultant to ensure its successful implementation throughout all the project stages. The case study demonstrates the idea of achieving the maximum benefits of BIM by initiating a coordinated modeling process in the early project stages (*i.e.*, level 2 BIM) and by using a partnering approach within a competitive procurement process. This approach also encouraged the early involvement of the contractor in the design process and ensured an interoperable modeling and collaboration process in a structured CDE that continued throughout the project stages with the support of several BIM applications, such as 3D visualization, clash detection, 4D simulations, BOQ Validation, constructability analysis, etc. The details of the project were not disclosed in this paper due to the confidentiality of the client and the anonymity of the project. Further, the author was part of the client's BIM consultancy team in a senior management capacity and was involved in strategy development and implementation processes. Therefore, the work presented in the following sections of this study can be classified as a practice-based description of the case study.

3.1. Project Description

The project was a mixed-use development project with commercial and residential spaces at the podium and with two 21-floor towers above the podium floors. The project was situated within the urban fabric of a busy city at a central business location, and it was required to seamlessly interact with the existing surrounding buildings, adjacent busy roads, and a close-by military establishment area. The project team was challenged with a highly accelerated schedule, aggressive cost target, and with the implementation of new tools and processes (*i.e.*, BIM), to meet the client expectations and set new construction standards in the region. Also, the project is owned by a semi-government real estate developer that has a strong portfolio in the region and in many countries worldwide.

3.2. The BIM Implementation Roadmap

A BIM implementation roadmap was developed and agreed with the client, based on the Client's strategic BIM implementation objectives. The strategic aspects of the plan included (1) the client's BIM vision and requirements for the project; (2) creation of a BIM Implementation Team (BIT); (3) procurement and training of the supply chain; (4) establishing IT infrastructure; and (5) development of project specific contract documents. Production and management plan addressed the needs and requirements of creating and maintaining project BIM models throughout various project stages. The roadmap of BIM implementation in the project is presented in Fig. (2).

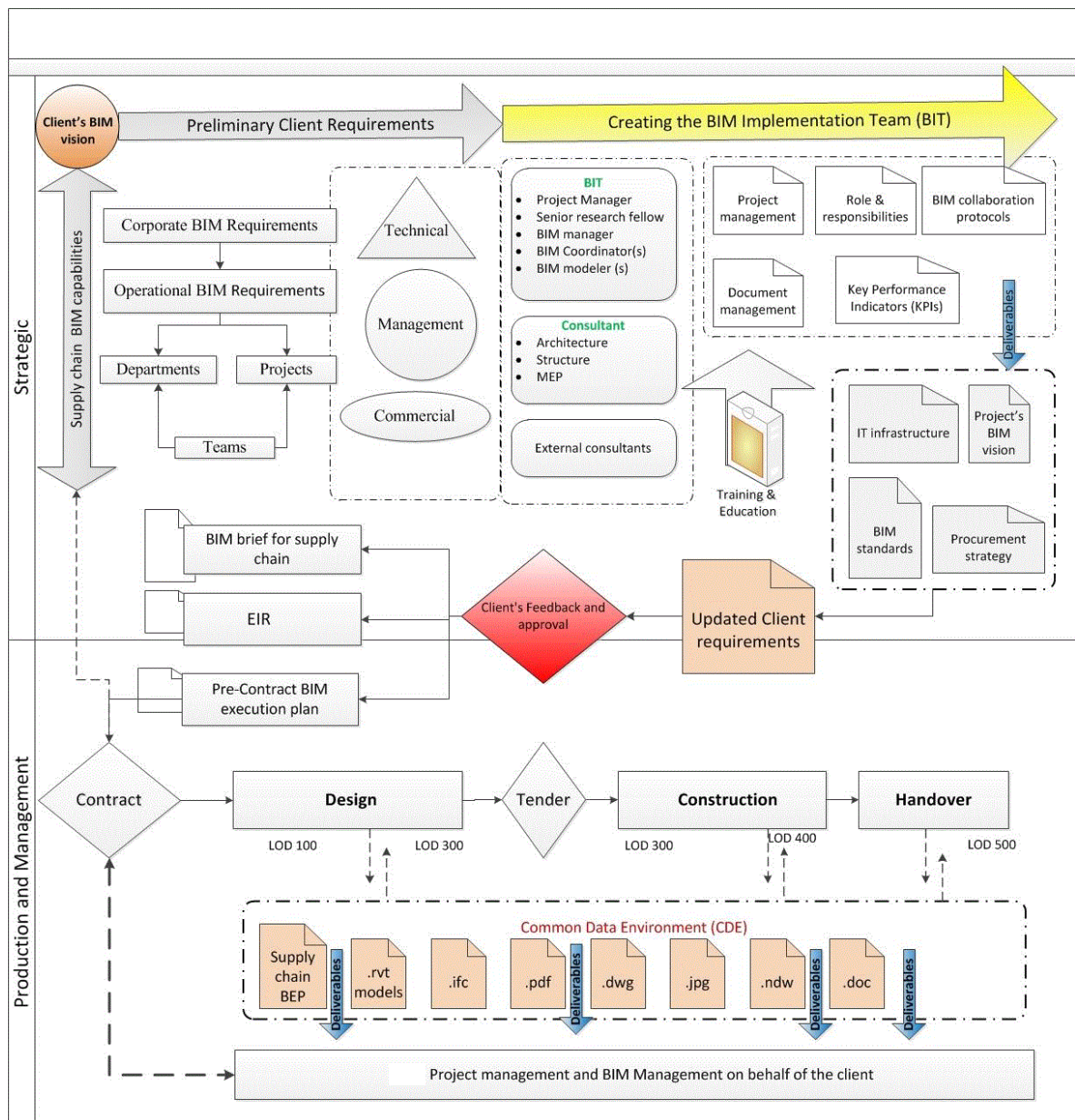


Fig. (2). Client-driven BIM implementation roadmap.

3.3. The BIM Initiative and Project Organization

The client decided to implement the BIM on this pilot project to explore its offered opportunities, especially in regard to reducing the capital cost and enhancing the digital facility management, and to extend the BIM initiative across all the projects. The client had an in-house construction team that conducted the feasibility study and initial project briefing. Also, the client engaged a project management consultant with the responsibility of the BIM management throughout the project stages. The role of the client’s BIM consultant was strategic and managerial and did not include model development at any stage of the project. The project management consultant was also responsible for the traditional

project management responsibilities (*i.e.*, contract administration, commercial management, design, and planning supervision, *etc.*).

3.4. Creating a BIT

The first challenge of implementing the BIM in the project was creating an eligible team to work in a collaborative environment and breaking the traditional status quo boundaries among the construction disciplines. This was achieved by creating a BIT from the start, where a clear definition of the roles and responsibilities, the key performance indicators, the BIM collaboration protocols, and the required procedures for the project and document management were outlined. In

addition to the client’s own in-house team, the following stakeholders formed an early project alliance to steer the BIM implementation on the project:

- Design consultants: They were responsible for the design and development of the BIM models.
- A preferred contractor and a sub-contractor advising on the constructability of the proposed design in the BIM models and collaborating on the engineering value of the project design.
- Project management and BIM consultants for the client: They consist of separate but co-located teams for the project management and BIM management tasks, but the BIM consultant was not responsible for the model development at any stage of the project.

3.5. Collaborative Procurement Strategy

The adopted procurement strategy was based on developing a special relationship between the project partners based on partnering principles [32]. The preferred suppliers were nominated and approved based on a “strategic partnership” agreement with the client. Also, the procurement strategy was built based on (1) strategic relationships, (2) partnering and collaborative legal framework, and (3) a phased procurement and competitive tendering process. Under this procurement strategy, the project partners were selected and engaged in the design, as well in the construction stage, as shown in Fig. (3) [21].

A “preferred” contractor was nominated at the early stages, e.g., the concept design stage, so that the collaboration with the consultant could start with the aim of producing a highly coordinated and planned design that leads to minimum design

errors, value engineering opportunities, and minimum Request For Information (RFI) during the construction phase. The “preferred” contractor and sub-contractor contributed to the design process by using 3D BIM models produced at different level of details during the design development process; however, they were required to bid at the tender stage along with other pre-qualified bidders in a traditional procurement process. Nevertheless, the preferred contractor and subcontractors, being involved in the design development stages, had an advantage, as they had in-depth knowledge of the project in comparison with their competitors in the bidding stage.

3.6. Employer Information Requirements (EIR) & BIM Execution Plan (BEP)

A key document for construction clients in the BIM implementation process is the EIR, which documents the technical, managerial, and commercial aspects of the BIM delivery from a client’s perspective [11]. The EIR also provided a contractual foundation to engage other key stakeholders in the BIM development and delivery process. Also, it was followed by a BEP, a master information delivery plan, and a task information delivery plan to further detail down the specifications and requirements of the EIR from each stakeholder. The information in the EIR ensured that useful information was being extracted from the evolving building information model and submitted to the employer (i.e., the client) at key milestones (also called data drops).

In this project, a two-stage process was employed to develop the EIR for the client. First, the preliminary client requirements were produced, which reflect the technical, commercial, and managerial aspects of the BIM based on the client’s understanding and vision of the BIM implementation. The client’s requirements were then refined during the BIM

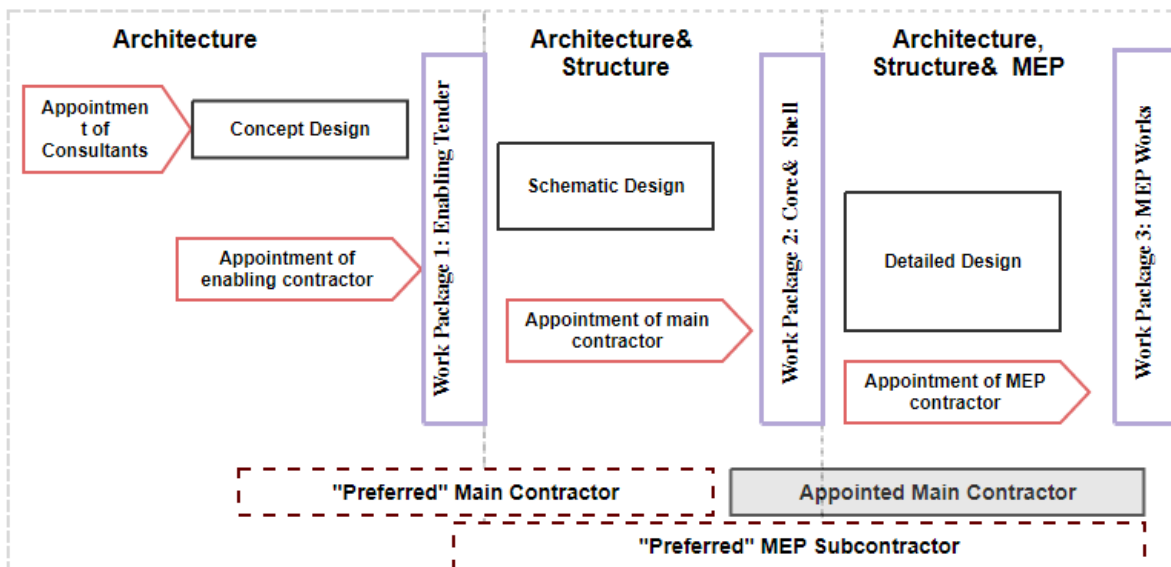


Fig. (3). Project procurement strategy [21].

development process at the design stage, thus producing an updated version of the EIR to be included in the contract documents for the appointment of the contractor. The EIR was used to develop a project BIM brief, a scope of the services for the supply chain, and a pre-contract BEP. The supply chain was asked to complete the BEP by articulating how they were going to achieve the requirements set out in the EIR, thus enabling competition and innovation across the supply chain. The stakeholders responsible for the various aspects of the BIM development process were required by the EIR to provide assurances that the delivered information at each data drop is complete. In addition, they were required to affirm that this information meets the EIR requirements and that it is developed to the agreed level of maturity for the stage at which the information is delivered using different Level of Detail (LOD) as per BS 1192-2 [11]. A LOD represents overall stage of information development in a BIM model from graphical objects definitions (*i.e.* LOD 100 and LOD 200) to fully defined parametric objects (LOD 300) and then includes assembly information (LOD 4000 and as built information (LOD 500), thus allowing the client and the project stakeholders to make informed decisions at every stage of the project.

3.7. Process Maps

The project benefited from the detailed process maps, which explained the information flow and role/responsibility of each project stakeholder, including the client, in the entire BIM execution process. The project used two sets of process maps as described below.

3.7.1. A Client-Based BIM Process Protocol

This is a high-level set of process maps that defined the roles and responsibilities of the partners along with the information flow at various phases of the project's life cycle. The project stages, department of the client organization, and project stakeholders were mapped together in a business process. A set of processes undertaken by different project stakeholders within each phase was outlined, which defined the roles and responsibilities of each stakeholder and the type of required decisions to ensure that each phase is effectively conducted by the relevant responsible authority. The process protocol also defined the "data drops" at the end of phase (similar to the PAS1192-2 information delivery cycle but more explicitly from a client's perspective). This assisted in the gradual (planned) development of the client asset information, not only in regard to the design and construction but also to the maintenance and operation of the project, thus ensuring that all stakeholders' requirements are met. The process protocol was used to guide the client at various stages of the BIM development process, specifically when it comes to what each partner is expected to do, the expected outcomes, the key decisions to be made, and the required information to achieve the EIR.

3.7.2. Information Exchange Workflows

The second set of process maps was developed for each phase of the project to define the detailed processes and information necessary for achieving the requirements set in the

EIR document. For example, the LOD 400 development, which was under the responsibility of the contractor, was clearly defined in an information exchange workflow map, thus explaining the key processes along with the inputs and outputs of different processes. This example is shown in Fig. (4), and it reflects the required processes and information for delivering the coordinated BIM model at the construction phase, thus leading to the as-built BIM.

The process maps were essential for guiding stakeholders throughout the design and construction phases. The partners could understand their roles and responsibilities and the type of information required for completing the BIM requirements. Most importantly, they could add value to the project by understanding why the information was required and how it could help in making better decisions. In addition, the project process protocol and clear information exchange workflows facilitated a collaborative project environment between all the project stakeholders throughout the project's lifecycle.

3.8. One Integrated Model for Supporting BIM Applications

The client-driven BIM requirement framework, clearly defined process maps, and partnering based procurement strategy helped the project partners to work together in a collaborative environment, and they shared the model with each stakeholder and created a single point of truth for the project information at the design stage for decision-making. The success of producing a consistent and fully coordinated design for the project relied on creating a single and integrated BIM model for the project, which allowed the simultaneous exploration of complex architectural spaces and the coordination of intricate building systems through 3D modeling, the rapid prototyping of details, and the extraction of 2-D documentation from the comprehensive BIM model. To minimize the interoperability issues, the project used a single software platform, Autodesk Revit Suite, to develop the BIM models (architecture, structure, and MEP), which were coordinated & shared through Bentley's ProjectWise, which was used as a CDE. The framework of the CDE is presented in Fig. (5) [21].

The Bentley's ProjectWise is a model collaboration platform that can support native Revit model exchanges, providing document management services with model-based project management support. The structure of the CDE is built upon the recommendations of the PAS1192-2; 2013, and the AIA-E202 suit of documents was used to define the legal aspects of the model sharing and exchange. All the project participants agreed NOT to over-model at any stage, so the design progression followed the implementation of the levels of development (LOD) as defined by the AIA BIM Protocol-E202. The model was progressively developed from LOD 100 to LOD 300 at the design stage, which was used to generate collaborative design reviews and clash detection, constructability reviews. The methodology and nomenclature of the PAS1192-2; 2013 was used to control the information sharing and collaboration tasks (*i.e.*, work in progress, shared, published, and archived). Further, the fully-coordinated clash-free BIM model (LOD 300) was handed over to the successful

bidder at the tender stage to further develop the LOD 400 model. The LOD 400 model was used to perform construction clash detection (e.g., clearances, etc.) and 4D simulations to support the planning process. In addition, it was used to track the contractor's progress and digitally report it to the client

using the CDE. It was the contractor's responsibility to update the LOD 400 model with the as-built information (floor by floor) and submit it to the client with the required information for the facility management tasks, thus delivering an as-built model (LOD 500) at the project handover.

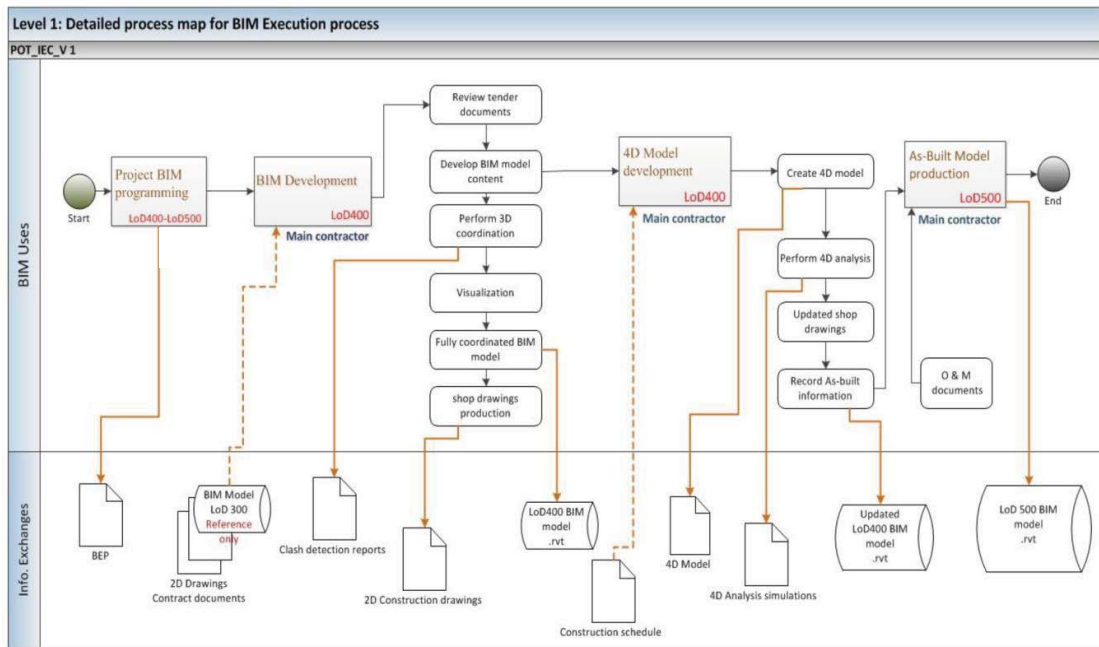


Fig (4). Level 1 process map for the contractors to produce an LOD500 model.

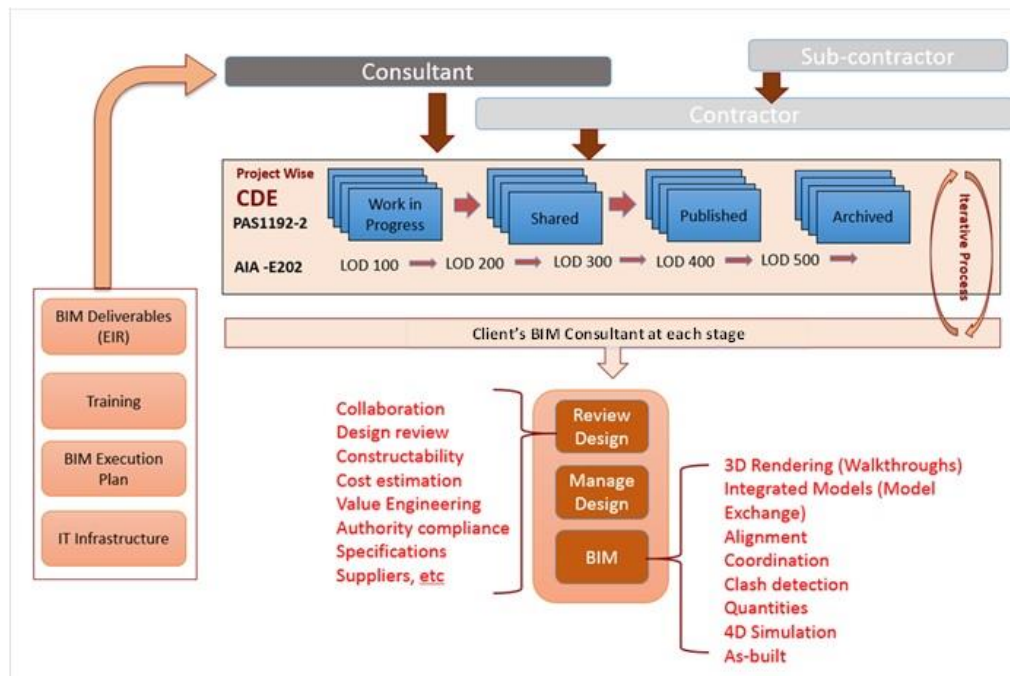


Fig (5). The structure of the project Common Data Environment (CDE) [21].

3.9. BIM Authoring and Coordination Tools Used

One objective of this pilot BIM implementation project for the client was determining the efficiency and effectiveness of the BIM authoring and coordination tools in generating fully coordinated, clash-free BIM models at various stages, which could produce accurate and reliable project documents (*i.e.*, drawings, specifications, *etc.*). Although the BIM models were used to produce project documents at tender stages, the use of the BIM models was contractually limited to “information only” due to the pilot nature of this project and the lack of experience of the supply chain partners. The BIM models were authored using Autodesk Revit platform (*i.e.*, Revit Architecture, Revit MEP, and Revit Structure), which used inputs from the 2D documents and drawings. All the models were exchanged using the CDE through Bentley’s ProjectWise. Moreover, Autodesk Navisworks was used to create 4D models (taking a feed from the Primavera P6 schedule and LOD 300 Revit model), and Autodesk BIM 360 Glue was used for the document management and cloud-enabled information for synchronization and collaboration. The interoperability issues were resolved using the IFC format and the XBIM IFC viewer and analyzer.

3.10. BIM Benefits Achieved

A strategically implemented BIM-enabled the client to lead and manage the development and implementation of BIM from the early project stages to the construction stage (*i.e.*, LOD 100 to LOD 500), ensuring that the client achieved the objectives of BIM implementation. The major BIM benefits for the client are summarized below.

3.10.1. 3D Model Aided Visualization

The BIM model was used to create 3D images and simulations, which significantly aided the client in the design reviews, including approving the design intent, analyzing the logistical and environmental impacts, identifying the cost implication, and making upfront decisions, leading to “no design changes” during the construction stage.

3.10.2. Design Clash Detection

A coordinated clash detection exercise was performed at LOD 100, LOD 200, and LOD 300. This exercise was led by the design consultant and reviewed by the client’s BIM consultant, ensuring that the final design model was fully coordinated and clash-free. All modeled building systems were monitored according to a predefined matrix of building systems (architectural, structural, HVAC, gas, drain, fire suspension, water supply, fire alarm, lighting, power, low voltage, lightning protection, and telecommunication). Autodesk Navisworks was used to run independent clash detection and track specific clash sets. For example, at LOD 200, 118 clashes were identified, impacting space function, aesthetics, cost, and time. If these clashes became RFIs and if each RFI requires at least 4 hours to solve, then potentially 474 hours (approximately 2 months) of labor were saved in the project. The outcomes were frequently reported to the client, along with an analysis of the implications of the clash management process on cost saving.

3.10.3. BOQ Validation and Tender Analysis

A fully coordinated and clash-free BIM (LOD300 model, *i.e.*, detailed design) automated the quantity take-off for the important items of BOQs (note that modeling all quantities in the BIM model was impractical for this project). The quantities were then validated against the design consultants’ BOQs (detailed design). The main purpose of this exercise was to determine the consultant’s major quantities by identifying discrepancies between those quantities and the quantity take-offs of the elements modeled in BIM. Subsequently, the tender prices at the tender stage were analyzed for competitive tending using the LoD300 BIM model, leveraging the maximum advantage to the client. The high-quality BIM models yielded accurate tender documents, which received only 22 queries during the tendering process (mainly logistical ones), and zero RFIs on design- and quantity-related queries. The completeness of the tender documents and quality of information achieved significant time and cost savings for the project.

3.10.4. 4D-Enabled Constructability Analysis and Planning

The BIM development and coordination process continued in the construction stage, as the contractor and MEP subcontractors were asked to update the same LOD 300 model to the LOD 400 model so as to eliminate the construction clashes and generate project shop drawings. The project construction team used “on the fly” coordination in a “BIG BIM ROOM,” where all the project stakeholders reviewed the BIM models and provided instant approvals in the weekly project meetings. This helped the project team in resolving the constructability issues earlier in the process, the results of which allowed the progression of the construction model (floor by floor) and helped in accelerating the production of effective and efficient delivery schedules.. Due to this closely collaborative work environment and easy access to design information, the result was a highly coordinated construction model (LOD400) that resulted in fewer RFI’s and change orders, thus saving a significant time at the construction stage. The main utilization of 4D modeling included (1) clarifying the “week-by-week” and “day-by-day” scope of work, (2) the on-time involvement of the subcontractors “when we require them,” and (3) the “just-in-time” material submittals and delivery.

3.10.5. As-Built Model for Facility Management

The project BIM model was updated during the construction stage by adding as-built information and linking it with the asset-management-related documents/manuals. This updated model (*i.e.*, LOD 500) captured as-built information in the BIM model, which can assist the client in its facility management operations after integration with the existing asset management practice of the organization.

3.11. Key Challenges in BIM Implementation

The literature review highlighted several key challenges in BIM implementation: (1) inexperienced supply chain partners, (2) traditional procurement and legal frameworks, (3) lack of technical expertise, and (4) technological barriers. In this

project, issues related to procurement and legal aspects were more prominent than those related to human capital and technology.

The most critical challenge in this project was developing a collaborative procurement strategy that facilitates collaborative work in a region that strictly operates using traditional competitive procurement settings. This challenge is amplified when the supply chain partners are lowly matured and local BIM standards and legal frameworks are unavailable. To overcome these issues, several workshops were conducted at the start of the project to determine the supply chain BIM capabilities. These workshops were followed by a comprehensive training program that empowered the project team with the required knowledge and skills for working in a collaborative BIM environment. The key steps in this stage are listed below:

- Defining the initial client requirements
- Conducting workshops to capture the relevant information and data
- Capturing the supply chain capabilities
- A scenario-based analysis of the BIM applications and available BIM capabilities (e.g., what is the BIM maturity level of the project partners when applying the BIM to clash detection at the design stage?)
- Delivering relevant training in the conducted workshops and seminars in the IEC head office.

The capturing and capability assessment requirements helped the project team in setting realistic BIM application targets, identifying the need for training and agreeing to a comprehensive set of client requirements on which the contract documents for the project are based (i.e., project BIM brief, EIR, and post-contract BEP). Consequently, the partners could agree on a collaborative procurement strategy at the forefront of the project, which continued throughout the project's development and delivery stages.

CONCLUSION

This paper presented a case study of the BIM implementation from the UAE, where a client-centric BIM mandate and strategy were employed to create a collaborative BIM environment. The paper described a client-driven approach to strategically introduce the BIM within a low BIM maturity market, create partnering relationships, empower supply chain partners, and achieving significant BIM benefits with minimum disruption to the existing work practices. Overall, this case study indicated that although the BIM requires a step-change in the work practices of the construction industry, it is still possible to successfully implement it with traditional procurement settings, which may be a critical feature in a certain market or for a client requirement. Also, using the BIM as a technology may not deliver BIM benefits to a project or to a client, so a client-driven structured approach must be employed to facilitate a collaborative environment. In addition, construction clients should find innovative practices, such as the partnering or preferred contractor approaches used in this project, to incorporate BIM processes into the existing business practices. This paper also suggested that client

organizations in low BIM maturity markets may require the services of specialized BIM consultants or in-house BIM teams to oversee the BIM development, coordination, and management processes. Overall, the study findings will assist construction industry clients and academia in redefining existing work practices to incorporate BIM-enabled processes and applications.

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AVAILABILITY OF DATA AND MATERIAL

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CONFLICT OF INTEREST

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