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Towards a Digitally Enabled Estate:
Project Capella

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Toward a Digitally Enabled Estate: Project Capella

This report details the transition of University of Cambridge Estate Management to a digitally enabled estate in line with the Government Construction Strategy. To support the implementation of Building Information Modelling (BIM) Level 2 and the use of digital technologies in the delivery and operation of assets, the University's Estate Management (EM) has developed a comprehensive information management strategy, including a range of processes and documentation. This report describes the uses of BIM technologies and implementation of BIM processes, examples of its benefits across RIBA stages and some of the main lessons learned from BIM Level 2 implementation during Project Capella, which forms part of the University's Biomedical Campus. The case study is based on interviews with client and contractor project managers and BIM managers. The report provides insights regarding elements associated with a successful BIM project and best practices for implementation of BIM Level 2. This is one of a number of case studies from across the campus showcasing the University's EM digitalisation process and the value of BIM.

Introduction

The University of Cambridge Estate—the buildings used for teaching, research and administrative activities—comprises 600,000 square metres across 350 operational facilities. The University's Estate Management (EM) is a multidisciplinary organisation responsible for the Estate's development, management and maintenance. The complex nature of the University Estate presents many challenges; for example, some buildings are 800 years old and are protected by English Heritage, and a wide range of information is needed to manage this portfolio. To enhance decision-making and ensure better outcomes, the future of EM is digital.

In creating a fully digital estate, one essential component is Building Information Modelling (BIM), which is needed to support capital delivery. The University has invested a significant amount of time and money to establish the use of BIM across the capital programme. EM has developed a comprehensive information management strategy, including processes and documentation, to support the delivery of BIM Level 2 in line with the Government Construction Strategy. BIM Level 2 requires an information exchange process coordinated between various systems and project participants (NBS, 2018). The goal of a digitally enabled estate is '*to provide easy, reliable and timely access to accurate and consistent information across the full asset lifecycle from master planning to maintenance and disposal or renewal*' (Hinton, 2017, p. 8). Guided by this vision, the EM team began to work towards implementing BIM Level 2 within the capital delivery programme by reviewing the potential uses and benefits of BIM for facilities management. BIM Level 2 has been implemented in all of the University's current projects, and the Capella building is one of the first projects to demonstrate the value of BIM.

Project Capella

Due for completion in the first quarter of 2019, Capella is an 18,000 m2 six-storey building containing state-of-the-art laboratories (Figure 1). Located on the Cambridge Biomedical Campus adjacent to Addenbrooke's Hospital, Capella will incorporate advanced research facilities, as well as a café, a seminar room and an event space. Designed by the Fairhurst Design Group and built by Kier Construction, the building will support a fully integrated stem-cell community, as its location at the Addenbrooke's Hospital site will facilitate greater collaboration between scientists and clinicians. Capella will house the Stem Cell Institute, the Cambridge Institute of Immunotherapeutic and Infectious Diseases and the Milner Therapeutics Institute.

Figure 1. The Capella building.

Source: Estate Management (2018) (Photo credit: Steve Hawkins).

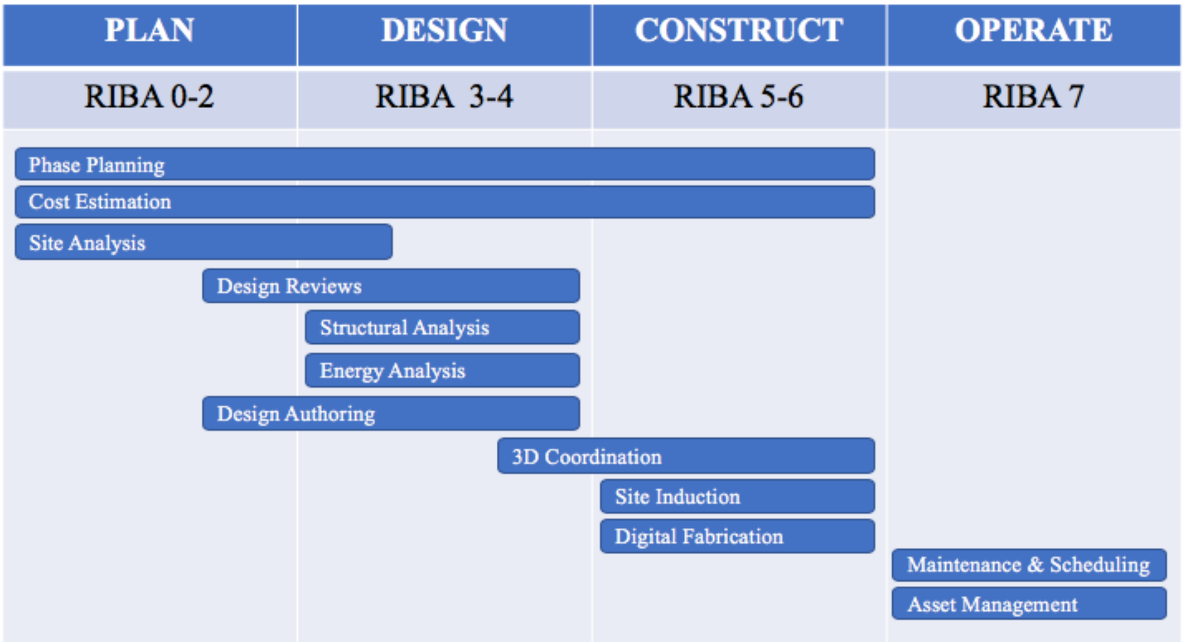
Capella was among the first projects to establish processes for implementing BIM and utilising that digital asset in the operational handover, based on a suite of documents and templates developed by the EM team to support BIM Level 2. These resources include Employer Information Requirements (EIR), Asset Information Requirements (AIR), a BIM Execution Plan (BEP), a Common Data Environment (CDE) guide, a BIM protocol and a Model Production and Delivery Table (MPDT). BIM Level 2 compliance was embedded in the tendering process, and the documentation was designed to support project stakeholders working in a BIM environment. The University requires BIM Level 2 compliance for all projects and has developed a procedure for assessing suppliers' capabilities and BIM maturity during the tendering process. This has resulted in greater awareness of BIM across the University and throughout the supply chain. The next section details the use of BIM technologies and BIM processes in project Capella.

Implementation and use of BIM in Capella

Building Information Modelling can be defined as "a collaborative way of working that facilitates early supply chain involvement; it is underpinned by digital technologies that unlock more efficient methods of designing, creating and maintaining the assets" (Digital Built Britain, 2015, p. 10). The adoption of BIM represents a paradigm shift in the construction industry (Donato et al., 2017; Zhao, 2017), and its use has increased in recent years, mostly due to its potential for improving the performance and efficiency of construction projects (Santos et al., 2017).

Many project delivery and asset operation tasks are likely to benefit from the incorporation of BIM and respective digital technologies (CIC, 2010). As part of the University's EIR, the various applications of BIM in Project Capella improved the efficiency of the construction process and brought value to the project in diverse ways (Figure 2). Capella is seen as a successful BIM project; based on interviews with stakeholders and analysis of secondary data, the project stayed within budget and achieved quality improvements, health and safety compliance and schedule adherence during superstructure construction. From the contractors' perspective, Capella showed the business what a successful BIM project looks like.

Figure 2. BIM uses over the RIBA stages.



In the early stages of the RIBA[1] plan of work, BIM was used for visual simulation, which one of the project managers described as a benefit when compared to conventional working practices:

> *'There was definitely a benefit in having the ability to fly through what the building would look like, in terms of marketing both to future users and to organisations who might be interested in donating money towards the construction costs. Whereas previously we would have shown just drawings or maybe a rendering, we were now able to show them a fly-through model, so that has worked well.'*

Using the visual simulation described above, BIM tools facilitated exploration and assessment of the preliminary design. The BIM model was also used to perform energy assessments and to look for ways of optimising the proposed design and reducing the structure's lifecycle costs. BIM also facilitated cost estimation throughout the project, as well as site planning. The BIM model was also used to evaluate properties in the area and the impact of Capella on the surrounding buildings, as described by one of the project managers:

> *'Obviously, the concern was how it would impact Cancer Research UK, which is the building opposite, isn't it? 'How is this going to affect us spatially when you're on site?' —it was used to demonstrate that kind of thing.'*

[1] The RIBA (Royal Institute of British Architects) Plan of Work is the definitive UK model for the building design and construction process.

BIM also supported phase planning at RIBA stage 4. The process employed a 4D model (that is, a 3D model with the added dimension of time) to plan the sequence of work. This kind of modelling is a powerful tool and provides a clear understanding of project milestones. In the developed and technical design stages, BIM tools were deployed for design authoring, design review, coordination and engineering analysis. The use of BIM models in the design review process improved quality and ultimately enhanced user satisfaction with the building, as highlighted by one of the project managers*:*

> *'I think what people are now getting … as we near completion, no one is surprised at what they see, in terms of the community that will move into it, because they have seen these images and these fly-throughs before. So, that was really useful.'*

Additionally, extensive coordination (using clash detection software to compare 3D models and identify field conflicts) resulted in improved outcomes as compared to the traditional way of working:

> *'Through exhaustive co-ordination and planning, deliveries were also reduced by 750 from initial estimates and worker hours halved compared with a traditional approach'* (Construction News, 2017). BIM was also applied to design and analysis of the structure, again resulting in clear benefits, according to one of the project managers:

> *'They used the BIM model in doing the structural analysis—not so much the analysis as the structure and the detail. So, when these components came to site, they fitted every time. And there are hundreds of them. So, I think that was really good.'*

Precast material was used in the construction phase for both the frame and the façade panels to minimise on-site labour and deliveries and to exploit the superior quality of factory construction. As reported by one project manager, the use of BIM in the construction phase yielded positive outcomes:

> *'Where I do think it worked well was on the structure, [which] was all precast. It was all made in the factory, delivered to site and bolted together. And it went incredibly well. In fact, the construction of the building envelope was really as good as I think it could have been.'*

BIM was also used for site induction as part of the construction-phase planning, which improved the health and safety of employees on site, as one of the project managers noted:

> *'In terms of a health and safety briefing, they made full use of it, and I think that was a very useful thing to have done. It was far better showing somebody on a screen almost in real time—well, not in real time, in fast time —how it was going to go together that week. So, that was really good.'*

Finally, the BIM model will support operation of the building, as highlighted by one of the project managers:

> *'I think the lesson learnt is we did really well on Capella when we look at how early we started […] we will be delivering a BIM model with a very detailed COBie[2] data drop that will provide masses of information for the rest of the life of that building or those buildings.'*

The University will link the facilities management system to a record model, making maintenance and operation of the facility more efficient. BIM will assist short- and long-term planning and decision-making. The next section outlines some of the main benefits of BIM as described in the interviews and secondary data.

[2] COBie (Construction Operations Building Information Exchange) is a non-proprietary data format for the publication of a subset of building information models focused on delivering asset data as distinct from geometric information (NBS, 2011).

Benefits of BIM implementation

The use of BIM over the course of the RIBA stages yielded a number of benefits (see Figures 3 and 4). As previously discussed, the use of BIM for site planning and visualisation in the initial stages facilitated selection of a design concept that was optimal for the surroundings, resulting in fewer changes and increasing end-user satisfaction. During the developed and technical design phases, the use of BIM tools for clash detection identified a range of issues that were solved in coordination meetings involving all of the stakeholders. The process enabled the team to make informed decisions and helped to keep the project on schedule. The BIM coordination process also reduced worker hours as compared to the traditional approach.

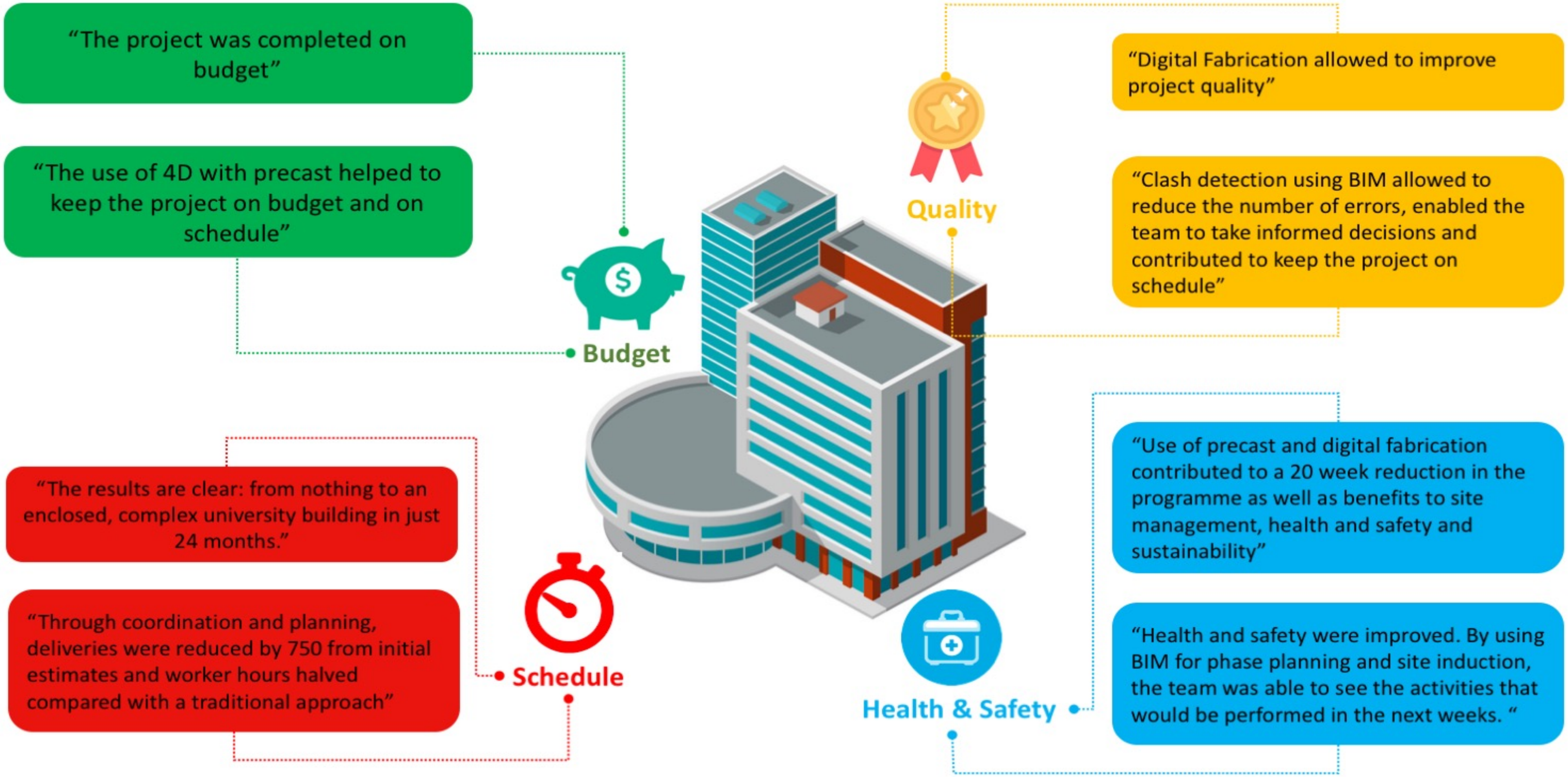
The use of prefabricated materials (precast concrete frame, panelised façade and steel-framed upper level) contributed to rapid construction (42 months) and overlapped with the design phase, reducing the initial programme timeline by 20 weeks. Enhanced coordination supported by BIM during the design stage also reduced construction time. Additionally, by developing a 4D model of the precast concrete frame and linking each element to its corresponding time interval, the project team was able to visualise the planned construction sequence and to monitor progress, which again helped to keep the project on schedule in that phase. Finally, showing construction workers the workflow for each week contributed to improved health and safety.

Achievement of these benefits was supported by a range of macro-level practices in compliance with the PAS 1192 suite of standards,[3] meso-level practices (i.e. at project and organisational levels) aligned with BIM and macro-level practices and micro-routines. The next section provides an overview of the practices and elements associated with successful execution and completion of a BIM project.

[3] The PAS (Publicly Available Specifications) set out the requirements for achieving BIM Level 2 by establishing a framework for collaborative working and information requirements.

Figure 3. BIM uses and benefits over the RIBA stages.

Figure 4. Benefits of BIM implementation in Capella.



Practices supporting BIM Level 2 delivery and improved project performance

A variety of new working practices associated with BIM are implemented in a BIM project, and some important practices were identified in the collected data. At the macro level of practices – (those related to compliance with the PAS 1192 suite of standards –), a variety of processes have been developed in compliance with PAS 1192-2:2013. Diverse requirements were defined in the EIR to align with Clause 5.3 of PAS 1192-2:2013. The EIR specifies aspects such as the University's strategic priorities, the technical information requirements (including software, information-exchange content and level of definition), details of the competence assessment to which bidders must respond, coordination and clash detection, the collaboration process, and a responsibility matrix setting out any disciplinary responsibilities.

The contractor worked closely with the University in setting up the EIR. According to the University's information specialist, this engagement was beneficial both for Capella and for future projects:

> *'We did a lot of 'reverse engineering', taking what we had in our EIR, going back to the contractor and their supply and seeing what they were answering in their BIM execution plans (BEPs). We're getting to the point now where not only does [the EIR] satisfy what the University wants, it allows the supply chain to actually deliver it.'* (Hinton, 2016)

The data also confirm the excellent sense of collaboration across all parties from the project's early stages:

> *'The sense of collaboration and commitment to a common goal was overtly apparent from our first pre-production meeting. It was as if we were talking to one organisation rather than the six or so parties around the table, including Cambridge themselves.'* (Mills, 2016)

This stakeholder involvement and close collaboration contributed to risk mitigation.

As noted earlier, the University also set up a procedure within the tendering process to evaluate supply chain capability to work on a BIM project. This procedure assesses the supplier's general competence (approach and ability to deliver to industry standards), as well as staff competence, drawing and modelling approaches, approach to collaborative working, technical capability, approach to security, understanding of BIM and previous BIM project experience. For internal team training purposes, a handbook developed by the EM team provided effective guidance for internal project managers on where to find relevant standards and information delivery requirements for a successful project outcome. The goal was to support internal project managers and to minimise certain risks, including over-specification, lack of common naming conventions, unclear roles and responsibilities, late completion, cost overruns and failure to deliver client objectives. The BIM handbook and support for internal project managers ease the transition to BIM, as one of the main challenges from the client perspective is the change in practices governing the work of internal project managers (Vass and Gustavsson, 2017).

Many meso-level practices also contributed to the success of the project. Workshops involving the client, the contractor and the supply chain enabled the team to improve and refine the project:

> *'Capella's rapid programme drove the contractor to seek constant improvement and refinement, with workshops on lessons learned conducted with the University and supply chain to evaluate progress as they went'* (Construction News, 2017). Bi-weekly design coordination workshops also helped to minimise errors. The coordination workshops enabled the team to develop a

comprehensive understanding of coordination issues and so maintain programme pace. As part of the practices adopted, the team established rule-based checks to support coordination, as well as a fortnightly cycle of model information exchanges. The micro-level practice (routinised action) of setting up an agenda prioritising more relevant issues and combining models for the coordination workshops also made a significant contribution.

Other practices that led to greater programme efficiency included developing a detailed 4D model for the precast concrete frame, linking each individual element to its programme time interval and tracking each element every week. Additionally, quality was enhanced by tracking each precast component from the moment it arrived on site through its installation while performing simultaneous checks. The micro-level routine of reintroducing information into the model after quality checks was also found to be important. In relation to health and safety, meetings (rather than mere verbal briefings) to explain the following week's workflow and how the frame would come together (based on the erection of the columns) proved effective in increasing on site awareness and practices. Other key lessons associated with successful BIM implementation were also identified, and these are discussed next.

Key lessons

Some of the lessons learned from Project Capella were also considered important for new projects.

Appointment of an external Information Manager

In the transition to BIM, the client commonly assigns an external party to support coordination across the project if no in-house staff are available (Vass and Gustavsson, 2017). In the case of Project Capella, the procurement route involved full design-and-build (DB). The contractor and consultant design team were appointed under an NEC3 contract at RIBA stage 1 as the responsible parties throughout the project.

The contractor was full responsible for the design and construction, but the University also appointed an external team including a project manager/BIM compliance manager who were responsible for reviewing the model for compliance with the contracted requirements. The appointment of an external party has been reported in the literature as a collaborative and innovative client strategy (Gustavsson, 2018). Since Capella, the University has appointed consultants who remain alongside the client throughout the process.

Stakeholder engagement

Engagement was identified as a crucial element in the project's success, and the design-and-build scheme supported the early engagement of the design and construction teams. The DB route facilitates BIM because the contractor is involved from the early design stages (Eastman et al., 2011). Specialist suppliers (e.g. structural, façade, MEP) came on board at the end of RIBA stage 2 and provided further early inputs. The analysis indicates that these steps helped to move the project from briefing to planning submission in less than eight months (Construction News, 2017).

Indeed, as one of the project managers noted, engagement of all parties is essential to exploit the full potential of BIM and related technologies; if any of the parties do not collaborate in the process, the full benefits will not be realised:

> *'While MEP contractors are supposed to install to drawings based on the BIM model, with clashes designed out, operatives frequently do not do so, negating the value of clash detection. It appears*

that individual services are installed where it is easiest to place them at the time of installation, and that the critical importance of exactly following the BIM generated construction drawings is not understood.'

The engagement and input of facilities management and maintenance teams are also crucial, as these teams are directly involved in managing the buildings. Facility managers are traditionally included in project delivery in only a very limited way in the later stages of facility handover (Kassem et al., 2015). In this case, the University has focused on involving the facilities management team and ensuring subsequent use of the model in the operational phase.

Technologies add only to rigorous processes

The implementation of BIM and digital technologies requires new working practices (Froese, 2010) and rigorous enactment of those practices. A project manager made the following point in relation to the use of BIM for coordination and clash detection:

'I think the other big issue on clash detection is that it will only detect the services that are drawn on it … it is only as good as the information that goes into it. So, if somebody fails to put a pipe on a drawing, or puts a pipe on at 50mm when it should actually be 450mm, those errors will still occur and BIM cannot pick them up. And then, of course, it looks like it will fit, but it doesn't.'

This confirms that while BIM technologies support existing tasks and create new working practices, the technology itself does not replace the task, and the basic design must be correct to enable BIM coordination and to exploit its full potential. As one project manager noted:

'A key point is that that the basic design of the complex MEP services in large buildings must be correct. While BIM seriously aids coordination, these services must be calculated correctly, with no omissions, to ensure full coordination via BIM at the design stage rather than resolving clashes on site.'

This again illustrates the importance of concerns such as level of detail and modelling accuracy in achieving the full potential of BIM.

Right attitude

One of the main barriers to BIM implementation relates to the human element. Along with appropriate training, the findings confirm that the right attitude is essential for successful BIM implementation, as one of the project managers indicated:

'So yes, it's more getting the right … Yes, you know, if someone's willing to give it a go, and they might not even have the experience or skill set at that point in time, but they've got the right attitude, so you can get through it together as a team'.

Behaviours and culture must change in order to move away from a traditional CAD-based environment to one that supports collaborative BIM (Matthews et al., 2018). In a BIM project, the approach to cultural change adopted by construction firms may make all the difference, and the client should consider this when assessing capabilities during the tendering process.

Conclusion

The University of Cambridge is in the process of creating a digitally enabled estate, and the implementation of BIM Level 2 is part of this holistic change. Procurement, tendering, contracts and internal processes have evolved to incorporate BIM deliverables that align with the University's objectives. The supply chain has responded positively to the challenge and has already realised the benefits of BIM implementation, as the Capella project demonstrates. BIM will also create value for the University in the operational phase. BIM models will be integrated in the University's facilities management system and will streamline the management process, eliminating duplication and identifying areas for improvement. The operational phase is the main contributor to the asset's lifecycle cost, and BIM's integrated data environment will improve the efficiency of facility management.

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